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FEED INGREDIENTS FOR CRUSTACEANS
NATURAL FOODS AND PROCESSED FEEDSTUFFS

by

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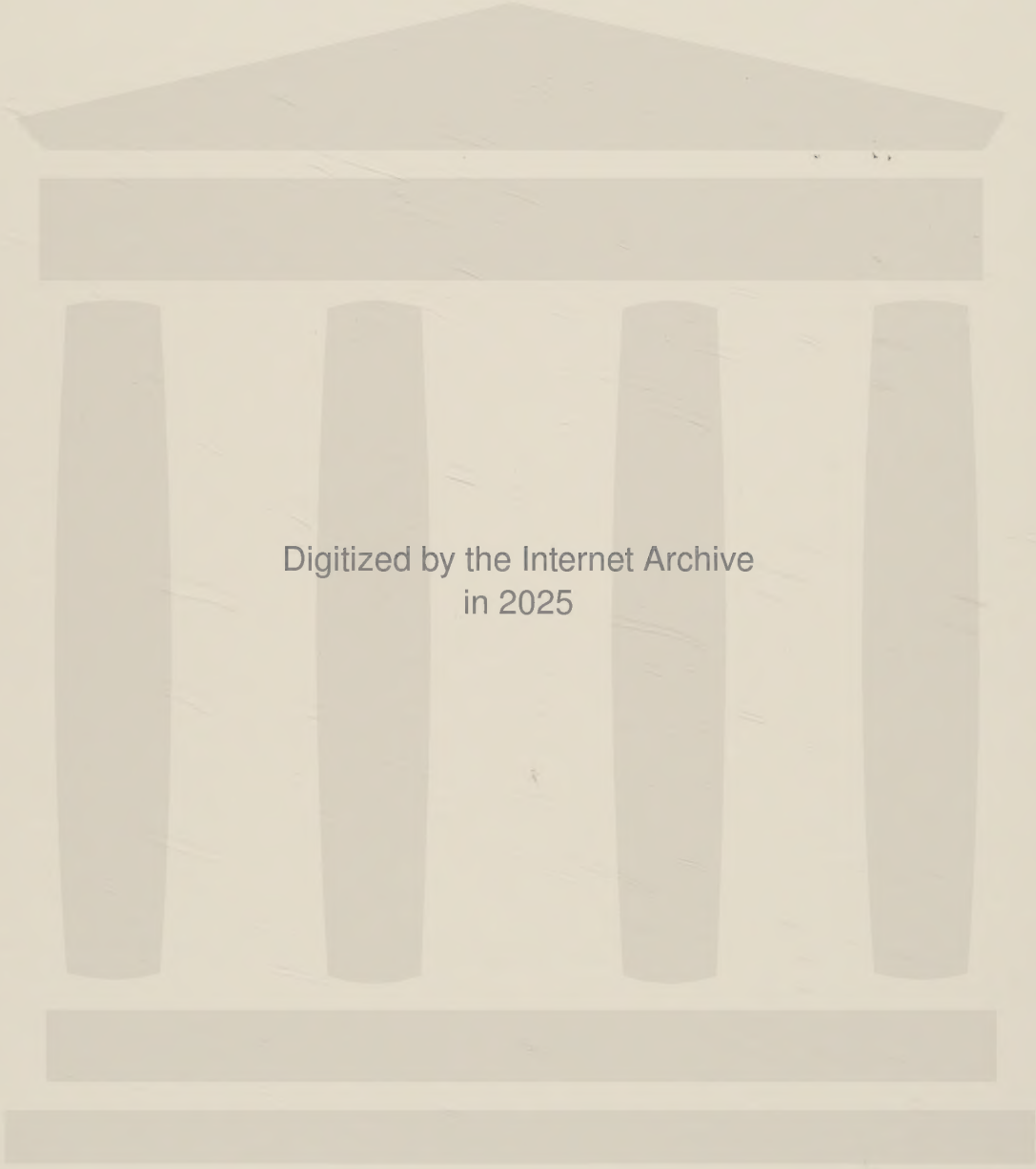

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PREPARATION OF THIS DOCUMENT

This document was prepared as part of the ongoing activities of the FAO Inland Water Resources and Aquaculture Service to help to meet the needs of aquaculture workers of Member Countries for synthesis of information in the field of aquaculture nutrition and feed development.

The document is the second of a series concerning the selection and use of feed ingredients for farmed finfish and crustaceans. The first document was concerned with feed ingredients for warmwater fishes and appeared as FAO Fisheries Circular No. 856.

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ABSTRACT

The paper reviews the natural feeding habits of decapod crustaceans and the major natural foods and processed feed ingredients used within compound aquafeeds for crustaceans, including fish and fishery by-product meals, terrestrial animal by-product meals, single cell proteins, aquatic plants, oilseeds and by-product meals, grain legumes and by-product meals, cereal grains and by-product meals and miscellaneous plant products. Information is also presented concerning the nutritional value of individual feed ingredient sources, together with their normal dietary inclusion levels. In addition, the document presents information on world crustacean aquaculture production and highlights the current trends and future prospects of feed ingredient usage within crustacean aquafeeds.

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1. INTRODUCTION

According to the most recent aquaculture production statistics (FAO, 1993) crustacean aquaculture production totalled 806,260 metric tonnes (mt) in 1991 (Table 1), up 7.0% from the previous year (Figure 1), and represented 16.8% of total world crustacean fishery landings (Table 2). Although crustaceans constituted only 4.9% of world aquaculture production by weight in 1991 (Figure 2), they represented 18.5% of world aquaculture production by value (Figure 3); the total reported value of crustacean aquaculture production in 1991 being 5.2 thousand million US $.

Asia remains the largest producer of farmed crustaceans (79.4% of world production; Figure 4) with marine penaeid shrimp forming the bulk of the crustacean aquaculture production (89.2% of total production in 1991; Figure 5-7). China was the largest producer of farmed crustaceans in 1991 (190,000 mt; 98.4% Penaeus chinensis), followed by Thailand (134,830 mt; 85.3% P. monodon, 5.8% P. merguiensis), Indonesia (113,980 mt; 61.9% P. monodon, 18.9% Metapenaeus sp., 15.8% P. merguiensis), Ecuador (106,108mt; 99.2% P. vannamei) and the Philippines (52,031 mt; 87.9% P. monodon, 8.2% P. indicus; FAO, 1993).

However, if crustacean aquaculture production is to maintain a modest growth rate of 5% per year into the next millennium then substantial inputs of fertilizer and feed will have to be provided. For example, according to the estimates of Chamberlain (1993) compound shrimp aquafeed production will have to increase from 810,000 mt in 1990 to 136,000 mt by the year 2000; the estimates are based on a shrimp production of 600,000 mt and 1,000,000 mt, a percent of shrimp production on feeds of 75% and 80%, and a feed conversion ratio of 1.8 and 1.7, for 1990 and the year 2000, respectively.

Although the majority of crustacean aquaculture operations are conducted within earth-pond farming systems (Rosenberry, 1992), almost all of the published information on the nutritive value of feed ingredients for crustaceans is derived from laboratory or indoor-tank based feeding trials. Whilst this information is essential for the formulation of complete diets intended for use within clear-water intensive tank farming systems the results cannot be directly applied with the same degree of confidence to pond farming systems where the cultured animals also derive a substantial part of dietary needs from naturally available pond food organisms; the relative contribution of natural food organisms to the overall nutritional budget of pond cultured crustaceans dictating the apparent nutritional value of the feed ingredient or artificial diet fed. For a review of the importance of natural food organisms in the overall nutritional budget of pond reared shrimp see Anderson et al. (1987), Bombeo-Tuburan, Guanzon and Schroeder (1993), Cam et al. (1991), Garcia-Casas and Lovell (1991), Lilyestrom et al. (1987), Moss et al. (1992), Omara-Alwala and Prior (1991), Stanley and Moore (1983), Trino et al. (1992) and Visscher et al. (1988). Despite this serious limitation, this paper attempts to review the published information concerning the use of natural foods and processed feed ingredients within aquafeeds for crustaceans and to highlight current trends and future prospects. The paper is the second of a series concerning the use of feed ingredients in aquaculture; the first being concerned with feed ingredients for warmwater fish (Tacon, 1993).

2. NATURAL FEEDING HABITS AND FEED INGREDIENTS

The starting point of a review on feed ingredients for crustaceans should first include an overview of the natural feeding habits and food preferences of the animals in question; the latter serving as a guide for the identification of potential feed ingredient sources for use by crustacean farmers and compound feed manufacturers alike. Table 3 summarizes the reported feeding habits of the major cultured decapods under natural and/or pond farming conditions.

On the basis of the information presented in Table 3 it is evident that the majority of cultured decapods have benthophagic omnivorous feeding habits. The major food items consumed include benthic invertebrates (primarily crustaceans, molluscs, annelids and insects) and associated detritus-based micro/meiofauna and flora. An important fact which emerges from the survey is that

cultured freshwater decapods generally feed lower on the aquatic food chain and on a wider variety of food organisms than their marine counterparts.

As a result of the natural feeding habits of decapod crustaceans a wide variety of natural food items have been used by aquaculturists as exogenous feed sources for their culture operations. Table 4 summarizes the major natural feed ingredients which have been successfully employed as complete or supplementary feeds (either live, fresh or frozen) for decapod crustacean postlarvae grow-out operations.

Fresh and frozen crustaceans have generally been found to be the preferred food item of farmed decapod crustaceans, including crayfish (Neomysis integer for Astacus astacus: Ackefors et al. 1989), lobster (adult Artemia sp. for Homarus americanus: Conklin et al. 1983; Conklin and Chang, 1983), crabs (mud crab Scylla serrata: Kathirvel and Srinivasagam, 1992; Jayamanne, 1992; Srinivasagam and Kathirvel, 1992) and shrimp (adult Artemia sp. and Metapenaeus bennettae for P. vannamei and P. esculentes, respectively: Hill and Wassenberg, 1987; Ogle and Beaugez, 1991). For example, Ogle and Beaugez (1991) determined the feeding preference of P. vannamei (7-11g body weight) for 15 different food items commonly used in shrimp maturation as follows: in order of preference, Artemia (crustacean), krill (crustacean), Maine bloodworms (annelid), oysters (mollusc), sandworms (annelid), anchovies (fish), Panama bloodworms (annelid), Nippai maturation pellets, Shigueno maturation pellets, conch (mollusc), squid (mollusc), Salmon-Frippak maturation pellets, Rangen maturation pellets and Argent maturation pellets. In view of the highly cannibalistic behaviour of most decapod crustaceans and the fact that crustacean feed items constitute a major part of their natural diet (Table 3), it is perhaps not surprising that crustaceans have been found to be the preferred food source of most cultured decapods; the nutritional composition and nutrient profile of natural crustacean food organisms approximating to the dietary nutritional requirements of cultured decapods for essential amino acids (EAA), essential fatty acids (EFA), minerals and vitamins.

In addition to the use of fresh or frozen crustacean fishery products (ie. whole shrimps, shrimp head waste, crabs etc) as supplementary feed items for crustacean grow-out and maturation programmes (Angell, 1992; Conklin and Chang, 1983; Hameed Ali and Dwivedi, 1977; Harrison, 1990; Liao and Chao ,1982; Ogle and Beaugez, 1991; Mito and Fukuhara, 1988), crustaceans are also an essential component of most crustacean hatchery operations in the form of Artemia nauplii as a live food organism for the developing larvae (Leger et al. 1986; Leger and Sorgeloos ,1992; Sorgeloos et al. 1983).

Despite the fact that nutritionally crustaceans may be the preferred food item for cultured decapods both in nature and in the laboratory, due to economical (ie. cost) and logistical (ie. availability) reasons the commonest natural food item used in crustacean grow-out and maturation operations has been molluscan food items such as bivalves (clams, mussels, oysters), cephlapods (squid) and to a lesser extent gastropods (snails: Bray and Lawrence, 1992; Harrison, 1990; Kripa and Joseph, 1992; Lim and Persyn, 1989; Mervane and Rivera, 1992; Mito and Fukuhara, 1988). For example, Ogle (1991), in a survey of 18 maturation facility managers cultivating P. vannamei, reported that squid was the most commonly used natural food (94%), followed by bloodworms (64%) and oysters (43%). Apparently, the utilization pattern observed was related more to availability and cost, and not necessarily due to shrimp preferences.

In general the nutritional value of live or fresh natural food organisms has been found to be higher than that of processed foods or artificially compounded diets (Chuang, 1990; Conklin and Chang, 1983; Cruz et al. 1990; Cuzon et al. 1981; Deshimaru et al. 1985; Fernandez and Puchal, 1979; Forster and Beard, 1973; How-Cheong, Gunasekera and Amandakoon, 1992; Lan and Pan, 1993; Luis and Batista, 1990; Smallridge et al. 1989). To a large extent this has been due to their superior water stability and generally higher biological value and digestibility; the latter usually resulting from a well balanced essential amino acid (EAA) and essential fatty acid (EFA) profile (Dall et al. 1991; Deshimaru et al. 1985; Divakaran and Duerr, 1988; Grabner et al. 1981; Lytle et al. 1988; Maugle et al. 1982; Middleditch et al. 1980; Pascual, 1989). For a review of the biochemical

composition of pond biota and the natural food items listed in Table 4 see Dall, Smith and Moore (1991), Hunter et al. (1987) and Tacon (1987).

3. PROCESSED FEED INGREDIENTS

Processed feed ingredients include all animal and plant food items which have been physically processed prior to feeding either by drying, fermenting, composting, grinding, pelleting or by mixing with other food items into a compound diet. Table 5 and Table 6 summarizes the major processed feed ingredients which have been used and tested within practical feeds for decapod postlarvae and provides suggestions for their maximum dietary inclusion level, respectively.

Apart from the difficulty of comparing results obtained from tank and pond feeding trials, a detailed analysis of the data presented in Table 5 is extremely difficult because of the absence of precise ingredient definitions within the majority of the studies presented, including 1) official ingredient name and description, 2) international feed number, 3) proximate chemical composition, and 4) ingredient particle size prior to mixing or feeding. For example, the 'shrimp meal' described in the study of Penaflorida (1989; declared proximate composition - 71.8% crude protein, 3.2% crude fat, 3.14% crude fibre and 16.91% ash) cannot be nutritionally compared with the 'shrimp meal' described in the study of Akiyama et al. (1989; declared proximate composition - 43.6 % crude protein; 4.5% crude fat, 10.7% crude fibre and 34.5% ash). Similarly, the studies of Cruz-Suarez and co-workers with shrimp (P. monodon) fed squid meal supplemented rations showed marked differences depending upon whether the studies were conducted in outdoor pond pens or within indoor tanks; pond pen reared shrimp growing significantly faster (by 70-80%) and having a better food conversion ratio (FCR of 2.2 for a reference diet and 1.7 for a 10% squid meal supplemented diet) than those reared in tanks (FCR of 3.4 for the reference diet and 2.8 for the 10% squid meal diet; Suarez, Ricque & Aquacop, 1992).

On a nutritional basis the best feed ingredients for decapod crustaceans are those whose biochemical composition approximates closest to that of the decapod's own body composition. Since proteins constitute the largest chemical group within the decapod body (with the exception of water) it follows therefore that the nutritive value of a feed ingredient will be governed to a large extent by its amino acid composition, and in particular upon the availability and profile of the essential amino acids (EAA) present. On the basis of the above hypothesis it is evident that the closer the EAA pattern of a protein source approximates to the EAA composition of the target species the higher its nutritional and potential biological value to the cultured animal (Aquacop & Cuzon, 1989; Deshimaru & Shigeno, 1972; Kanazawa, 1989; Lim & Persyn, 1989; Sarac et al. 1993).

For example, Penaflorida (1989) calculated the essential amino acid index (EAAI)[1/]

1/

$$EAAI = \sqrt[n]{\frac{aa_1}{AA_1} \times \frac{aa_2}{AA_2} \times \frac{aa_3}{AA_3} \times \ldots\ldots \times \frac{aa_n}{AA_n}}$$

Where aa and AA = EAA ratio in feed and animal respectively (ratio calculated for each individual EAA as a percentage of the total EAA)

of potential protein sources for P. monodon by comparing the ratio of EAAs in individual feedstuffs to that of whole P. monodon juveniles, and reported ingredient EAAIs as follows; shrimp meal (Acetes sp.) 0.98, squid meal, white fish meal 0.96, herring fish meal 0.95, slipmouth fish meal 0.94, peruvian fish meal, tuna fish meal 0.92, soybean meal 0.87, casein 0.81, kangkong meal 0.55, ipil-ipil meal 0.54, sweet potato meal, acacia meal, tamarind meal 0.53, gelatin 0.52, and zein 0.29 (EAAI values were assigned a maximum of 1.0 and a minimum of 0.1, where 0.9 is

generally indicative of a good quality protein, useful around 0.8 and inadequate below 0.7). The fact that shrimp meal (whole Acetes sp.) and squid meal emerged as having the highest EAAI, and consequently, the most suited EAA profile for cultured shrimp is a confirmation of the high nutritional value usually ascribed to these feed ingredients for shrimp in the wild (in form of live crustaceans or molluscs; Table 3) or under practical farming conditions either as live or fresh food organisms (Table 4) or as processed feed ingredients within compound feeds (Ahamad Ali, 1992; Akiyama et al. 1991; Aquacop & Cuzon, 1989; Cruz-Ricque et al. 1987; Hartnoll & Salama, 1992; Meyers, 1986, 1989; Ravishankar & Keshavanath, 1988; Tacon, 1986; Table 6).

Although EAAI is a useful tool for predicting protein quality it does not take into account the biological availability of the individual amino acids present and consequently should be supported by in vitro and/or in vivo ingredient digestibility measurements (Akiyama et al. 1989; Eid & Matty, 1989; Lan & Pan, 1993; Miyazono & Inoue, 1989; Reigh et al. 1990; Tacon, 1993a). For the practical applicability of digestibility measurements and ease of comparison of results between laboratories the particle size of the test ingredient should be reported and digestibility measurements determined using a practical range of different dietary inclusion levels. Unfortunately, at present the majority of published studies on feed ingredient digestibility do not specify the particle size of the ingredients tested and determine nutrient digestibility at a single fixed hypothetical dietary inclusion level.

In addition to nutrient content, the nutritional value of a feed ingredient is dependent upon its physical characteristics and properties, including particle size, density, water solubility and stability, and pelletability. For example, Palaniswamy and Ahmad Ali (1991) found that feed ingredients in compound diets should be ground to a particle size of 200 um for maximum pellet water stability and feed utilization efficiency in P. indicus. By contrast, Ostrowski-Meissner, Duerr and Vannatta (1992) reported that with P. vannamei the reverse was true; fine grinding not improving feed digestibility within cold pelleted diets, although improving pellet stability. Similarly, although shrimp meal may have an ideal EAA profile its use in compound feeds is normally limited by the physical property of its high fibre content which exerts a negative effect on nutrient digestibility and pellet water stability.

4. FUTURE PROSPECTS

At present the commercial marine shrimp farming industry is almost totally dependent upon the use of marine based feed ingredient sources within compound aquafeeds; 25-50% of the total compound shrimp diet usually being in the form of fish meal, and to a lesser extent shrimp meal, squid meal, and fish oil (Table 6). For example, of the estimated 1,078 thousand metric tonnes of fish meal used in compound finfish and crustacean aquafeeds in 1992, by far the largest consumer of fish meal was marine shrimp (32% of the total fish meal used; Figure 8). According to the estimates of Chamberlain (1992) fish meal and fish oil usage within shrimp aquafeeds are expected to increase by 50% and 77% from about 202,500 mt and 24,300 mt in 1990 to 340,000 and 68,000 mt by the year 2000, respectively (the values are based on a fixed dietary fish meal and fish oil level of 25% and 3%, respectively). On the basis of the above projected consumption rates and the maintenance of a constant world fish meal production rate of between 5.8 and 6.4 million mt for the duration of the coming decade (Table 7, Figure 9), it is estimated that approximately 20% of the total world resources of fish meal and fish oil would be used within compound aquafeeds by the year 2000 (as compared with 14% in 1990; Figure 10). The importance of fish meal to the compound aquafeed manufacturing sector can be clearly illustrated by the development of the shrimp farming sector in Thailand (Jantrarotai, 1993), where shrimp production has increased from 11,550 mt in 1983 to 155,000 mt in 1992 (Figure 11), and has been followed by a corresponding increase in domestic shrimp aquafeed manufacture from 23,000 mt in 1983 to 320,000 mt in 1992 (Figure 11), decreased domestic fish meal exports from 128,007 mt in 1983 to 11,035 mt in 1991 (Figure 12), and increased international fish meal imports from 0 mt in 1983 to 53,119 mt in 1991 (Figure 12).

Whilst there is no doubt of the high nutritional value of fish meal and marine feed ingredient sources for cultured shrimp and other crustaceans, they represent an expensive and finite commodity which are also competitively utilized within livestock feeds (ie. fish meal, Figure 9) or used for human consumption (Figure 13, Chamberlain, 1993; Tacon, 1993). Furthermore, increasing raw ingredient and feed manufacturing costs, coupled with an often static and/or decreasing market value for cultured shrimp, necessitates that the shrimp farmer reduce production costs so as to maintain profitability. Consequently, since food and feeding usually represents the largest single operating cost item of semi-intensive and intensive shrimp farming enterprises (Chong, 1992), clearly future research emphasis must be placed on the development of improved on-farm feed management strategies (Tacon, 1992) or through the development of feeding strategies aimed at reducing feed costs, including:

. Replacement of marine based feed ingredients within compound feeds with alternative less expensive protein sources and overcoming inherent nutrient imbalances either through the blending of complementary feed ingredients (Akiyama, Dominy & Lawrence, 1991; Akiyama, 1993; Kanazawa, 1989, 1993; Tacon & Jackson, 1985) or through dietary supplementation with feeding attractants (Hartati & Briggs, 1993) and/or stabilized free amino acids (Chen, Leu & Roelants, 1992; Lim, 1993) so as to obtain the desired overall dietary EAA and nutrient profile;

. Maximising the role played by naturally available pond food organisms in the overall nutritional budget of the farmed species through improved pond fertilization and water management techniques. At present almost all commercial shrimp farmers employ a complete diet feeding strategy for their semi-intensive shrimp ponds with no allowance provided within the artificial diets used for natural food availability (Akiyama, 1991, 1993; Tacon, 1992; Trino et al. 1992). For example, the studies of Teichert-Coddington, Green and Parkman (1991) in Honduras showed that chicken litter (applied at a rate of 220 kg/ha/week) could profitably substitute for high cost pelleted shrimp feeds (26% crude protein diet) during the first eight to nine weeks of the pond grow-out phase with P. vannamei/P. stylirostris (89:11) at a stocking density of 5 animals per m^2;

. Development of low-cost supplementary diets, as compared to high-cost complete diets, for use within semi-intensive pond farming systems at low-to-moderate shrimp stocking densities (ie. 5-15 animals/m^2; Akiyama, 1991, 1993; Tacon, 1992). For example, the studies of Wood and co-workers in India showed there was no difference in the growth of pond reared shrimp (P. monodon, 10 animals/m^2) fed a high-cost nutrient dense complete pelleted diet (as used for intensive shrimp culture) or a locally produced dough-ball costing one third of the price (Wood et al. 1992); and

. The selection of cultured decapod species which feed lower down on the aquatic food chain and which can make maximum use of naturally available pond food organisms with minimal exogenous supplementary feed inputs (ie. freshwater crustaceans, P. indicus, P. merguiensis, P. vannamei, Metapenaeus sp.).

5. REFERENCES

Ackefors, H., R. Gydemo and L. Westin, 1989. Growth and survival of juvenile crayfish, Astacus astacus in relation to food and density, p.365-373. In N.De Pauw, E.Jaspers, H.Ackefors and N.Wilkins. Aquaculture - a biotechnology in progress. European Aquaculture Society, Bredene, Belgium.

Ahamad Ali, S., 1992. Evaluation of some animal and plant protein sources in the diet of the shrimp Penaeus indicus. Asian Fisheries Science, 5:277-289.

Apud, F.D., N. Deatras and K. Gonzales, 1981. Feeding behaviour and food preference of Penaeus monodon Fabricus with scrap Tilapia mossambica. Fisheries Research Journal of the Philippines 6(1):27-31.

Aquacop, 1976. Incorporation of vegetable proteins into a diet for the freshwater prawn Macrobrachium rosenbergii. Aquaculture 8:71-80.

Aquacop, 1977. Reproduction in captivity and growth of Penaeus monodon Fabricus in Polynesia, pp.927-945. In J.W.Avualt (ed.). Proceedings of the 8th Annual Workshop of the World Mariculture Society. Louisiana State University Press, Baton Rouge, USA.

Aquacop and G. Cuzon, 1989. Selected ingredients for shrimp feed, p.405-412. In Advances in Tropical Aquaculture, 20 February to 4 March 1989, Tahiti. AQUACOP/IFREMER Actes de Colloque 9.

Akiyama, D.M., 1988. Soybean meal utilization by marine shrimp. Paper presented at the ACOS World Congress on Vegetable Protein Utilization in Human Food and Animal Feedstuffs, Singapore 2-7 October 1988, 27p.

Akiyama, D.M., 1991. Future considerations for the aquaculture feed industry, p.5-9. In D.M.Akiyama and R.K.H.Tan, (eds.). Proceedings of the Aquaculture Feed Processing and Nutrition Workshop, Thailand and Indonesia September 19-25, 1991. American Soybean Association, Singapore.

Akiyama, D.M., 1993. Semi-extensive shrimp farm management. ASA Technical Bulletin, MITA(P) No. 518/12/92, Vol. AQ 38 1993/3, American Soybean Association, Singapore, 20p.

Akiyama, D.M., W.G. Dominy and A.L. Lawrence, 1991. Penaeid shrimp nutrition for the commercial feed industry: revised, p.80-98. In D.M.Akiyama and R.K.H.Tan, (eds.). Proceedings of the Aquaculture Feed Processing and Nutrition Workshop, Thailand and Indonesia September 19-25, 1991. American Soybean Association, Singapore.

Akiyama, D.M., S.R. Coelho, A.L. Lawrence and E.H. Robinson, 1989. Apparent digestibility of feedstuffs by the marine shrimp Penaeus vannamei Boone. Nippon Suisan Gakkaishi, 55(1):91-98.

Anderson, R.K., P.L. Parker and A.L. Lawrence, 1987. A 13C/12C tracer study of the utilization of presented feed by a commercially important shrimp Penaeus vannamei in a pond growout system. Journal of the World Aquaculture Society 18(3):148-155.

Angell, C.A., 1988. The BOBP (Bay of Bengal Programme) experience in shrimp feed formulation. Bay of Bengal News no. 29:8-11.

Angell, C.A., 1992. (ed.). Report of the seminar on the mud crab culture and trade held in Thailand, Nov. 5-8 1991, Bay of Bengal Programme. Report No. BOBP/REP/51. Project GCP/RAS/118/MUL, Madras, India, 246 p.

Anggawati, A.M., 1992. Fish protein in juvenile tiger shrimp diets. Feed Magazine, 2/92:22-24.

Arnstein, D.R. and T.W. Beard, 1975. Induced maturation of the prawn Penaeus orientalis Kishinouye in the laboratory by means of eyestalk removal. Aquaculture, 5:411-412.

Ashmore, S.B., R.W. Stanely, L.B. Moore and S.R. Malecha, 1986. Effect on growth and apparent digestibility of diets varying in grain source and protein level in Macrobrachium rosenbergii. Journal of the World Mariculture Society, 16:205-216.

Avault, J.W. and M.W. Brunson, 1990. Crawfish forage and feeding systems. Reviews in Aquatic Sciences, 3(1):1-10.

Balazs, G.H. and E. Ross, 1976. Effect of protein source and level on growth and performance of the captive freshwater prawn, Macrobrachium rosenbergii. Aquaculture, 7:299-313.

Balazs, G.H., E. Ross and C.C. Brooks, 1973. Preliminary studies on the preparation and feeding of crustacean diets. Aquaculture, 2:369-377.

Beard, T.W. and J.F. Wickins, 1980. The breeding of Penaeus monodon Fabricus in laboratory recirculating systems. Aquaculture, 20:79-89.

Beard, T.W., J.F. Wickins and D.R. Arnstein, 1977. The breeding and growth of Penaeus merguiensis De Man in laboratory recirculation systems. Aquaculture, 10:275-289.

Behrends, L.L., J.B. Kingsley and A.H. Price, 1985. Use of ethanol production by-products for producing microalgae, tilapia and freshwater prawns. Agricultural Research Branch, National Fertilizer Development Centre, Tennessee Valley Authority, Muscle Shoals, Alabama, USA., 34pp.

Bombeo-Tuburan I., N.G. Guanzon and G.L. Schroeder, 1993. Production of Penaeus monodon (Fabricus) using four natural food types in an extensive system. Aquaculture, 112:57-65.

Boonyaratpalin, M. and M.B. New, 1982. Evaluation of diets for Macrobrachium rosenbergii reared in concrete ponds, p.249-256. In M.B.New, (ed.). Giant prawn farming. Elsevier (Publishers) Ltd, Amsterdam, Holland.

Boonyaratpalin, M. and P. Vorasayan, 1983. Brief note on the state of the art of Macrobrachium culture in Thailand. Bangkok (Thailand). 11 p. FAO Field Document, FAO Project: RAS/76/003 - Establish Network of Aquaculture Centres in Asia. NACA Working Paper 83/7.

Bostock, T., 1991. Better feeds for small-scale shrimp farmers. Bay of Bengal News No. 42:22-26.

Brand, C.W. and L.B. Colvin, 1977. Compounded diets for early postlarval Penaeus californiensis, p.811-820. In Proceedings of the 8th Annual Meeting of the World Mariculture Society, Louisiana State University, Baton Rouge, USA.

Bray, W.A. and A.L. Lawrence, 1992. Reproduction of Penaeus species in captivity, p.93-170. In A.W. Fast and L.J. Lester (eds.), Marine shrimp culture: principles and practices. Elsevier Science Publishers, Amsterdam, Holland.

Bray, W.A., A.L. Lawrence and L.J. Lester, 1990. Reproduction of eyestalk-ablated Penaeus stylirostris fed various levels of total dietary lipid. Journal of the World Aquaculture Society, 21:41-52.

Browdy, C.L., A. Hadani, T.M. Samocha and Y. Loya, 1989. An evaluation of frozen Artemia as a dietary supplement for the simulation of reproduction in penaeid shrimp, p.617-623 N.De Pauw, E.Jaspers, H.Ackefors and N.Wilkins, (eds.). European Aquaculture Society, Bredene, Belgium.

Brown, A., J. McVey, B.S. Middleditch and A.L. Lawrence, 1979. Maturation of white shrimp (Penaeus setiferus) in captivity. Proceedings of the World Mariculture Society 10:435-444.

Brown, P.B., J.E. Wetzel, A. Spacie and A. Konopka, 1992. Evaluation of naturally-occurring organisms as food for juvenile crayfish Procambarus clarkii. Journal of the World Aquaculture Society, 23(3):211-216.

Buck, D.H., R.J. Baur and C. Rose, 1978. Polyculture of Chinese carps in ponds with swine wastes. In R.Smitherman, W.Shelton and J.Grover, (eds.). Culture of Exotic Fish Conference Proceedings of the American Fisheries Society, Auburn, Alabama USA.

Cam, D., P.-E. Rollet, A. Mariotti and J. Guillaume, 1991. Contribution relative de la productivite naturelle et del'aliment compose dans la nutrition de Penaeus japonicus eleve en conditions semi-intensives. Aquatic Living Resources 4:175-180.

Capuzzo, J.M. and B.A. Lancaster, 1979. The effects of dietary carbohydrate levels on protein utilization in the american lobster, Homarus americanus. Proceedings of the World Mariculture Society 10:689.

Carver, L.A., D.M. Akiyama and W.G. Dominy, 1988. Processing of wet shrimp heads and squid viscera with soy meal by a dry extrusion process. Presented at the AOCS World Congress on Vegetable Protein Utilization in Human Food and animal Feedstuffs, Singapore, 2-7 October 1988, 9p.

Castille, F.L. and A.L. Lawrence, 1989. The effects of deleting dietary constituents from pelleted feeds on the growth of shrimp in the presence of natural foods in ponds (Abstract). Journal of the World Aquaculture Society, 20(1):22A.

Catacutan, M.R., 1991. Growth and fatty acid composition of Penaeus monodon juveniles fed various lipids. Bamidgeh, 43(2):47-56.

Celada, J.D., J.M. Carral, V.R. Gaudioso, C. Temino and R. Fernandez, 1989. Response of juvenile crayfish (Pacifastacus leniusculus Dana) to several fresh and artificially compounded diets. Aquaculture, 76:67-78.

Celada, J.D., J.M. Carral, V.R. Gaudioso, J. Gonzalez, C. Lopez-Baisson and R. Fernandez, 1993. Survival and growth of juvenile freshwater crayfish Pacifastacus leniusculus Dana fed two raw diets and two commercial formulated feeds. Journal of the World Aquaculture Society, 24(1):108-11.

Chamberlain, G.W., 1991. Shrimp farming in Indonesia. 1. Growout techniques. World Aquaculture, 22(2):12-27.

Chamberlain, G.W., 1992. Shrimp farming in Indonesia. 4. Feeds for the shrimp industry. World Aquaculture, 23(2):38-40.

Chamberlain, G.W., 1993. Aquaculture trends and feed projections. World Aquaculture, 24(1):19-29.

Chamberlain, G.W. and A.L. Lawrence, 1981. Maturation, production, and growth of Penaeus vannamei and P. stylirostris fed natural diets. Journal of the World Mariculture Society, 12(1):209-224.

Chen, H.-Y. and H.-F. Lin, 1992. Effects of different Artemia diets on the growth and digestive enzyme activities of early post-larval Penaeus monodon. Asian Fisheries Science, 5:73-81.

Chen, H.-Y., Z.P. Zein-Eldin and D.V. Aldrich, 1985. Combined effects of shrimp size and dietary protein source on growth of Penaeus setiferus and P. vannamei. Journal of the World Mariculture Society, 16:288-296.

Chen, H.-Y., Y.-T. Leu and I. Roelants, 1992. Effective supplementation of arginine in the diets of juvenile marine shrimp, Penaeus monodon. Asian Fisheries Science, 5:73-81.

Chiang, P. and I.C. Liao, 1985. The practice of grass prawn (Penaeus monodon) culture in Taiwan from 1968 to 1984. Journal of the World Mariculture Society, 16:297-315.

Chong, K.-C., 1992. Improving profitability of shrimp aquaculture, p.81-98. In H. de Saram and T. Singh (eds.) Shrimp '92 Hong Kong, Proceedings of the 3rd Global Conference of the Shrimp Industry, Hongkong, 14-16 September 1992. Infofish (Publishers), Kuala Lumpur, Malaysia.

Chong, V.C. and A. Sasekumar, 1981. Food and feeding habits of the white prawn Penaeus merguiensis. Marine Ecology - Progress Series 5:185-191.

Chow, K.W., 1984. Diet development for sea bass, grouper and penaeid shrimp culture in Malaysia. (A survey of fish feeds and initiation of programme). Pages 1-18 In Coastal aquaculture development, Malaysia. Rome (Italy). p. 1-18. FAO Field Document, FAO Project: MAL/77/008 - Coastal Aquaculture Demonstration and Training. Field Document 2.

Chuang, J.L., 1990. Nutrient requirements, feeding and culturing practices of Penaeus monodon: A review. F.Hoffmann-La Roche Ltd., Basel, Switzerland, 62p.

Clifford, H.C. and R.W. Brick, 1979. Protein utilization in the freshwater shrimp. Proceedings of the World Mariculture Society, 10:195-208.

Cobb, J.S. and D. Wang, 1985. Fisheries biology of lobsters and crayfishes. Pages 167-248 in A.J.Provenzano, editor. The Biology of Crustacea, Volume 10 - Economic Aspects: Fisheries and Culture. Academic Press, New York, USA.

Conklin, D.E. and E.S. Chang, 1983. Grow-out techniques for the American lobster, Homarus americanus, p.277-286. In J.P.McVey, (ed.). CRC Handbook of Mariculture, Volume 1: Crustacean Aquaculture. CRC Press Inc., Boca Raton, USA.

Conklin, D.E., 1980. Nutrition, p.277-300. In J.S.Cobb and B.F.Phillips, (eds.). The Biology and Management of Lobsters, Volume 1. Academic Press, New York, USA.

Conklin, D.E., M.J. Goldblatt, C.E. Bordner, N.A. Baum and T.B. McCormick, 1978. Artificial diets for the lobster, Homarus americanus, a reevaluation. Proceedings of the Annual Meeting of the World Mariculture Society 9:243-250.

Conklin, D.E., L.R. D'Abramo and K. Norman-Boudreau, 1983. Lobster nutrition, p.413-423. In J.P.McVey, (ed.). CRC Handbook of Mariculture, Volume 1: Crustacean Aquaculture. CRC Press Inc., Boca Raton, USA.

Corbin, J.S., M.M. Fujimoto and T.Y. Iwai, 1983. Feeding practices and nutritional considerations for Macrobrachium rosenbergii culture in Hawaii, p.391-412. In J.P.McVey, (ed.). CRC Handbook of Mariculture, Volume 1: Crustacean Aquaculture. CRC Press Inc., Boca Raton, USA.

Corre, K.G., 1988. Nursery and grow-out operation and management of Penaeus monodon (Fabricus), p.247-267. In J.V.Juario and L.V.Benitez, (eds.). Perspectives in Aquaculture Development in Southeast Asia and Japan. Proceedings of the Seminar on Aquaculture Development in Southeast Asia, Iloilo City, Philippines, 8-12 September 1987.

Costa, H.H. and T.B. Wanninayake, 1986. Food, feeding and fecundity of the giant freshwater prawn Macrobrachium rosenbergii from natural habits in Sri Lanka, p.555-558 in J.L.Maclean, L.B.Dizon and L.V.Hosillos, (eds.). The First Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines.

Crockett, J., L. Sturmer, A.L. Lawrence and J. Whitson, 1988. Polychaete biomass as an indicator of natural productivity in penaeid shrimp culture ponds. Program Abstracts of the 19th Annual Meeting of the World Aquaculture Society. Journal of the World Aquaculture Society 19(1).

Cruz, F., A. Gozalbo and J.M. San Feliu, 1990. Composicion, contenido calorico, crecimento y supervivencia de juveniles de Penaeus japonicus, Bate 1888, alimentos con diferentes dietas. Informacion Technica Scientifica Marina (Barcelona), 159:3-15.

Cruz-Ricque, E.L., J. Guillaume, G. Cuzon and Aquacop., 1987. Squid protein effect on growth of four penaeid shrimp. Journal of the World Aquaculture Society, 18(4):209-217.

Cruz-Suarez, E.L., J. Guillaume and A. Van Wormhoudt, 1987. Effect of various levels of squid protein on growth and some biochemical parameters of Penaeus japonicus juveniles. Nippon Suisan Gakkaishi, 53(11):2083-2088.

Cruz-Suarez, E.L., D. Ricque and J. A. Martinez-Vega, 1991. Evaluation of two shrimp byproducts as protein sources for Penaeus vannamei feed. World Aquaculture Society Program Abstracts, June 16-20 1991, Puerto Rico.

Cruz-Suarez, E.L., D. Ricque and Aquacop., 1992. Effect of squid meal on growth of Penaeus monodon juveniles reared in pond pens and tanks. Aquaculture, 106:293-299.

Cruz-Suarez, E.L., R. Robledo de Leon and D. Ricque, 1992. Evaluation of tuna byproducts meal as a protein source for Penaeus vannamei shrimp feed in a controlled environment (Abstract). Paper presented at Aquaculture '92, Orlando, Florida, 21-25 May 1992. Aquaculture '92: Growing toward the 21st Century. 1992. 73p.

Cruz-Suarez, E.L., D. Ricque-Marie, J.A. Martinez-Vega and P. Wesche-Ebeling, 1993. Evaluation of two shrimp by-product meals as protein sources in diets for Penaeus vannamei. Aquaculture, 115:53-62.

Cuzon, G., 1988. Shrimp nutrition consultancy report from 12/04/88 to 04/05/88. Paris (France). 33 p. FAO Field Document, FAO Project: CUB/86/004 - Asistencia para el Desarrollo del Cultivo del Camaron en Cuba.

Cuzon, G., R.D. Santos, M. Hew and G. Poullaouec, 1981. Use of Spirulina in shrimp (Penaeus japonicus) diet. Journal of the World Mariculture Society, 12(2):282-291.

Cuzon, G., M. Hew, D. Cognie and P. Soletchnik, 1982. Time lag effect of feeding on growth of juvenile shrimp, Penaeus japonicus Bate. Aquaculture, 29:33-44.

D'Abramo, L.R., C.E. Bordner, D.E. Conklin, N.A. Baum and K.E. Norman-Boudreau, 1981. Successful artificial diets for the culture of juvenile lobsters. Proceedings of the World Mariculture Society, 12:325.

D'Abramo, L.R., J.S. Wright, K.H. Wright, C.E. Bordner and D.E. Conklin, 1985. Sterol requirements of cultured juvenile crayfish Pacifastacus leniusculus. Aquaculture, 49:245-255.

Dall, W., D.M. Smith and L.E. Moore, 1991. Biochemical composition of some prey species of Penaeus esculentus Haswell (Penaeidae: Decapoda). Aquaculture, 96:151-166.

Dall, W., D.M. Smith and L.E. Moore, 1992. The composition of Zostera capricorni seeds: a seasonal natural food of juvenile Penaeus esculentus Haswell (Penaeidae: Decapoda). Aquaculture, 100:75-83.

De la Cruz, M.C., G. Erazo and M.N. Bautista, 1989. Effect of storage temperature on the quality of diets for the prawn, Penaeus monodon (Fabricus). Aquaculture, 80:87-95.

Deshimaru, O., 1981. Studies on nutrition and diet for prawn, Penaeus japonicus. Memoirs of the Kagoshima Prefecturate Fisheries Experimental Station No.12:1-128.

Deshimaru, O. and K. Shigeno, 1972. Introduction to the artificial diet for prawn Penaeus japonicus. Aquaculture, 1:115-133.

Deshimaru, O., K. Kuroki, M.A. Mazid and S. Kitamura, 1985. Nutritional quality of compounded diets for prawn Penaeus monodon. Bulletin of the Japanese Society of Scientific Fisheries, 51(6):1037-1044.

Djunaidah, I.S., Kasnadi, Yahya and Sugianto, 1990. Fresh anchovies (Stolephorus sp.) as an alternative supplemental feed in P. monodon nursery ponds, p.189-191. In W.G.Yap, (ed.). Proceedings of the Shrimp Culture Industry Workshop, Jepara, Indonesia, 25-28 September 1989.

Divakaran, S. and E.O. Duerr, 1988. Characterization of leaching rate in shrimp feeds: measurements of loss in weight and organic matter. Program Abstracts of the 19th Annual Meeting of the World Aquaculture Society. Journal of the World Aquaculture Society, 19(1).

Dominy, W.G. and H. Ako, 1988. Utilization of blood meal as a protein ingredient in the diet of the marine shrimp Penaeus vannamei. Aquaculture, 70:289-299.

Dominy, W.G. and C. Lim, 1991. Evaluation of soybean meal co-extruded with wet squid viscera as a source of protein in shrimp feeds. World Aquaculture Society Program Abstracts, June 16-20 1991, Puerto Rico.

Dominy, W.G., G.R. Huber and D.J. Castaldo, 1991. Wet extrusion: texturized proteins for aquafeeds. Feed International, February 91:33-36.

Eid, A.E. and A.J. Matty, 1989. Simple in vitro method for measuring protein digestibility. Aquaculture, 79:111-119.

Eusebio, P.S, 1991. Effect of dehulling on the nutritive value of some leguminous seeds as protein sources for tiger prawn, Penaeus monodon, juveniles. Aquaculture, 99:297-308.

Evans, P.D. and K.H. Mann, 1977. Selection of prey by American lobsters (Homarus americanus) when offered a choice between sea urchins and crabs. Journal of the Fisheries Research Board of Canada, 34:2203-2207.

FAO, Fishery Information, Data and Statistics Service, 1993. Aquaculture production 1985-1991. FAO Fisheries Circular No. 815, Rev.5, Rome, FAO. 1993. 213 p.

FAO, 1993a. FAO yearbook: Fishery statistics - catches and landings, Vol. 72, 1992. FAO Statistics Series No. 111. Rome, FAO. 1993. 653p.

FAO, 1993b. FAO yearbook: Fishery statistics - commodities, Vol. 73, 1991. FAO Statistics Series No. 113. Rome, FAO. 1993. 395p.

Faranda, F., A. Salleo, G. Lo Paro and A. Manganaro, 1984. Quantitative requirement of Penaeus kerathurus for a natural unprocessed diet. Aquaculture, 37:125-131.

Feller, R.J., 1991. Dietary analysis of penaeid shrimp: the immunoassay approach, p.141-156. In P.F.Deloach, W.J.Dougherty and M.A.Davidson, (eds.). Frontiers of Shrimp Research. Developments in Aquaculture and Fisheries Science 22.

Fenucci, J.L. and Z.P. Zein-Eldin, 1976. Evaluation of squid mantle meal as a protein source in penaeid nutrition, p.601-605. In T.V.R.Pillay and W.A.Dill, (eds.). Advances in Aquaculture, Fishing News (Books) Ltd, Farnham, England.

Fenucci, J.L., Z.P. Zein-Eldin and A.L. Lawrence, 1980. The nutritional response of two penaeid species to various levels of squid meal in a prepared feed. Proceedings of the World Mariculture Society, 11:403-409.

Fernandez, R. and F. Puchal, 1979. Studies on compounded diets for Penaeus kerathurus shrimp. Proceedings of the World Mariculture Society, 10:781-787.

Fernandez, R.R. and A. Lawrence, 1988. The nutritional responses of three species of postlarval penaeid shrimp to cottonseed meal. Abstracts of the 19th Annual Meeting of the World Aquaculture Society. Journal of the World Aquaculture Society, 19(1).

Forster, J.M.E. and T.W. Beard, 1973. Growth experiments with the prawn Palaemon serratus Pennant fed with fresh and compounded foods. Fishery Investigations Series II, Volume 27, Number 7, Ministry of Agriculture, Fisheries and Food, London, England, 16p.

Freeman, D.W., E.O. Duerr and K.M. Leber, 1992. Use of bagasse as a feed input to semi-intensive shrimp growout ponds. Journal of the World Aquaculture Society, 23(1):23-30.

Galgani, F. and H.J. Ceccaldi, 1988. The effect of the incorporation of soya bean and fish meals in the diet on the growth and digestive enzymes of Penaeus vannamei. Aquatic Living Resources (France), 1(3):181-187

Galgani, M.-L., G. Cuzon, F. Galgani and J. Goguenheim, 1989. Influence of the diet on the reproduction of Penaeus indicus in captivity. Aquaculture, 81:337-350.

Galgani, M.-L. and Aquacop (J. Goguenheim, F. Galgani and G. Cuzon), 1989a. Influence du regime alimentaire sur la reproduction en captivitede Penaeus vannamei et Penaeus stylirostris. Aquaculture 80:97-109 (In French).

Gallagher, M.L., 1976. The nutritional requirements of juvenile lobster, Homarus americanus. Ph.D thesis, University of California, Davis.

Garces, C.L. and J.M. Heinen., 1993. Evaluation of beef liver, fruits, and vegetables as dietary supplements for indoor nursery culture of freshwater prawns Macrobrachium rosenbergii. Journal of the World Aquaculture Society, 24(1):58-65.

Garcia-Casas, I., 1990. Response of Penaeus vannamei and Penaeus stylirostris to various supplemental feeding regimes in semi-intensively managed earthen ponds in Honduras. M.Sc. thesis, Department of Fisheries and Allied Aquaculture, Auburn University, Alabama, 33p.

Garcia-Casas, I. and R.T. Lovell, 1991. Response of Penaeus vannamei and Penaeus stylirostris to various supplemental feeding regimes in semi-intensively managed earthen ponds in Honduras. World Aquaculture Society Program Abstracts, June 16-20 1991, Puerto Rico.

Garson, G.I., R.M. Pretto and D.B. Rouse, 1986. Effects of manures and pelleted feeds on survival, growth, and yield of Penaeus stylirostris and Penaeus vannamei in Panama. Aquaculture, 59:45-52.

George, M.J., 1972. The food and feeding habits of Metapenaeus monoceros (Fabricus), p.178. In T.V.R.Pillay, (ed.). Coastal Aquaculture in the Indo-Pacific Region. Papers presented at the Indo-Pacific Fisheries Council Symposium on Coastal Aquaculture, Bangkok, Thailand, 18-21 November 1970.

Goddard, J.S., 1988. Food and feeding, p.145-166. In D.M.Holdich and R.S.Lowery, editors. Freshwater Crayfish - Biology, Management and Exploitation. Croom Helm, London and Sidney.

Godfred, J., K. Sriraman, N. Ramanathan and T. Kannupandi, 1991. Feed formulation and its effect on the growth of four species of penaeid shrimp. Aquaculture Europe, 16(1):26-28.

Goswami, U. and S.C. Goswami, 1979. Formulation of cheaper artificial feeds for shrimp culture: preliminary biochemical, physical and biological evaluation. Aquaculture, 16:309-317.

Grabner, M., W. Wieser and R. Lackner, 1981. The suitability of frozen and freeze-dried zooplankton as food for fish larvae: a biochemical test program. Aquaculture, 26:85-94.

Hameed Ali, K. and S.N. Dwivedi, 1977. Acceleration of prawn growth by cauterisation of eye stalks and using Acetes indicus as supplementary feed. Journal of the Indian Fisheries Association of Bombay, 2-3:9p.

Haroon, Y.A.K., 1990. Freshwater prawn farming trials in Bangladesh. NAGA -The ICLARM Quarterly, July 1990:6-7.

Harpaz, S. and E.A. Schmalbach, 1986. Improved growth and health of the Malaysian prawn, Macrobrachium rosenbergii, by addition of fresh leaves to the artificial diet. Aquaculture, 55:81-85.

Harrison, K.E., 1990. The role of nutrition in maturation, reproduction and embryonic development of decapod crustaceans: a review. Journal of Shellfish Research, 9(1):1-28.

Hartati, R. and M.R.P. Briggs, 1993. Effect of feeding attractants on the behaviour and performance of juvenile Penaeus monodon Fabricus. Aquaculture and Fisheries Management, 24:613-624.

Hartnoll, R.G. and A.J. Salama, 1992. The effect of protein source on the growth of the prawn Palaemon elegans Rathke, 1837 (Decapoda, Caridea). Crustaceana, 63(1):81-90.

Hassan, I.A., Sayuthi, S. and C.S. Chiam, 1984. Fabrication of feed suitable for smallholder aquaculture, p.261-278. In Coastal aquaculture development, Malaysia. Rome (Italy). FAO Field Document, FAO Project: MAL/77/008 - Coastal Aquaculture Demonstration and Training. FAO Field Document 2.

Heinen, J.M. and M.J. Mensi, 1991. Feeds and feeding schedules for indoor nursery culture of postlarval freshwater prawn Macrobrachium rosenbergii. Journal of the World Aquaculture Society, 22(2):118-127.

Herrick, F.H., 1909. Natural history of the American Lobster. Bulletin of the United States Bureau of Fisheries, 29:149-408.

Hessen, D.O., 1989. Crayfish food and nutrition, p.164-174. **In** J.Sturdal, K.Westman and P.I.Bergan, (eds.). Crayfish Culture in Europe. Report of the Workshop on Crayfish Culture, 16-19 November 1987, Trondheim, Norway.

Hessen, D.O., A. Agerberg, G. Kjellberg, T. Odelstrom and K. Westman, 1989. Food, nutrition, growth, reproduction and genetics, p.39-48. In J.Sturdal, K.Westman and P.I.Bergan, editors. Crayfish Culture in Europe. Report of the Workshop on Crayfish Culture, 16-19 November 1987, Trondheim, Norway.

Hill, B.J., 1976. Natural food, foregut clearance rate and activity of the crab Scylla serrata. Marine Biology, 34:109-116.

Hill, B.J. and T.J. Wassenberg, 1987. Feeding behaviour of adult tiger prawns, Penaeus escultentus, under laboratory conditions. Australian Journal of Marine and Freshwater Research, 38:183-190.

How-Cheong, C. and H.P. Amandakoon, 1992. Formulation of artificial feeds for mud crab culture: a preliminary biochemical, physical and biological evaluation, p.179-184. In C.A. Angell (ed.). Report of the seminar on the mud crab culture and trade held in Thailand, Nov. 5-8 1991, Bay of Bengal Programme. Report No. BOBP/REP/51. Project GCP/RAS/118/MUL, Madras, India, 246 p.

Huner, J.V., 1984. Growth responses of juvenile male crawfish, Procambarus clarkii, fed artificial diets supplemented with Egeria densa, a vascular aquatic plant. Journal of the World Mariculture Society, 15:129-131.

Huner, J.V., S.P. Meyers and J.W. Avault, 1975. Response and growth of freshwater crayfish to an extruded, water-stable diet, p.149-157. In J.W.Avault, (ed.). Freshwater Crayfish. Papers from the Second International Symposium on Freshwater Crayfish, Baton Rouge, Louisiana, USA.

Hunter, B., G. Pruder and J. Wyban, 1987. Biochemical composition of pond biota, shrimp ingesta, and relative growth of Penaeus vannamei in earthen ponds. Journal of the World Aquaculture Society, 18(3):162-174.

Jantrarotai, W., 1993. The aquatic feed industry and the role of government on the development of aquaculture in Thailand. NIFI Newsletter, 3(1):3, July 1993, National Inland Fisheries Institute, Bangkok, Thailand.

Jayamanne, S.C., 1992. The mud crab fishery in Sri Lanka, p.41-48. In C.A. Angell (editor) Report of the seminar on the mud crab culture and trade held in Thailand, Nov. 5-8 1991. Bay of Bengal Programme. Report No. BOBP/REP/51. Project GCP/RAS/118/MUL, Madras, India, 246 p.

Kanazawa, A., 1984. Feed formulation for penaeid shrimp, sea bass, grouper and rabbitfish culture in Malaysia, p.61-78. In Coastal aquaculture development, Malaysia. Rome (Italy). FAO Field Document, FAO Project: MAL/77/008 - Coastal Aquaculture Demonstration and Training. FAO Field Document 2.

Kanazawa, A., 1989. Protein requirements of penaeid shrimp, p.261-270. In Advances in Tropical Aquaculture, 20 February to 4 March 1989, Tahiti. AQUACOP/IFREMER Actes de Colloque 9.

Kathirvel, M. and J. Jrinivasagam, 1992. Resource and exploitation of mud crab Scylla serrata (Forska) in India, p.84-94. In Report of the seminar on the mud crab culture and trade held in Thailand, 5-8 Nov. 1991. Bay of Bengal Programme, Report No. BOBP/REP/51. Project GCP/RAS/118/MUL, Madras, India, 246 p.

Kohler, C.C. and S.P. Krueger, 1985. Use of pressed brewer's grain as feed for freshwater prawn (Macrobrachium rosenbergii). Journal of the World Mariculture Society, 16:181-182.

Kongkeo, H., 1990. Fish feed technologist's (consultant) report (1 January to 28 February 1990). Rome (Italy). 29 p. FAO Field Document, FAO Project: THA/89/003 - Fish Nutrition and Aquaculture Diets.

Koshio, S., A. Kanazawa and S.-I. Teshima, 1992. Search for effective combination with crab protein for the larval Kuruma prawn Penaeus japonicus. Nippon Suisan Gakkaishi, 58(6):1083-1089.

Koshio, S., A. Kanazawa and S.-I. Teshima, 1992a. Nutritional evaluation of dietary soybean protein for juvenile freshwater prawn Macrobrachium rosenbergii. Nippon Suisan Gakkaishi, 58(5):965-970.

Koshio, S., J.D. Castell and R.K. O'Dor, 1992. The effect of different dietary energy levels in crab-protein based diets on digestibility, oxygen consumption, and ammonia excretion of bilaterally eyestalk-ablated and intact juvenile lobsters, Homarus americanus. Aquaculture, 108:285-297.

Kripa, V. and M. Joseph, 1992. Growth response of Penaeus monodon Fabricus to pelleted feeds of different protein sources. In National Seminar on Prawn Feeds and National Workshop on the Impact of Coastal Aquaculture on Environment, 25-26 February 1992, The Fisheries College and Research Institute (Tuticorin) and The Asian Fisheries Society (Indian Branch) Souvenir (Abstract).

Kungvankij, P., A.G.J. Tacon, K. Corre, B.P. Pudadera, G. Taleon, E. Borlongan and I.O. Potestas, 1986. Acetes as prime food for Penaeus monodon larval, p.581-584. In J.L. Maclean, L.B. Dizon and L.V. Hasillos (eds.) the First Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines.

Lan, C.C. and B.S. Pan, 1993. In-vitro digestibility simulating the proteolysis of feed protein in the midgut land of grass shrimp (Penaeus monodon). Aquaculture, 109:59-70.

Law, a.T., K.S.S. Chin, K.J. Ang and M.S. Kamarudin, 1990. Digestibility of low-cot ingredients in pelleted feeds by Macrobrachium rosenbergii (De Man), p.333-336. In R. Hirana and I. Hanyo (eds). The Second Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines.

Lawrence, A.L. and F.C. Castille, 1988. The nutritional response of postlarval Penaeus vannamei to meat and bone meal. Program Abstracts of the 19th Annual Meeting of the World Aquaculture Society. Journal of the World Aquaculture Society, 19(1).

Lawrence, A.L., F.L. Castille, L.N. Sturmer and D.M. Akiyama, 1986. Nutritional response of marine shrimp to different levels of soybean meal in feeds. Paper presented at the USA-ROC and ROC-USA Economic Council's Tenth Anniversary Joint Business Conference, September 1986, Taipei, Taiwan, Republic of China, 9p.

Lawrence, A.L., Y. Akamine, B.S. Middleditch, G. Chamberlain and D. Hutchins, 1980. Maturation and reproduction of Penaeus setiferus in captivity. Proceedings of the World Mariculture Society, 11:481-487.

Leber, K.M. and G.D. Pruder, 1988. Using experimental microcosms in shrimp research: the growth enhancing effect of shrimp pond water. Journal of the World Aquaculture Society, 19(4):197-203.

Leber, K.M., W.G. Dominy and G.D. Pruder, 1988. Shrimp feeding responses to food web manipulations in experimental growout ponds. Program Abstracts of the 19th Annual Meeting of the World Aquaculture Society. Journal of the World Aquaculture Society, 19(1).

Lee, C.L. and D.R. Fielder, 1982. Induced spawning in the freshwater prawn, Macrobrachium australiense Holthuis, 1950 (Crustacea: Decapoda: Palaemonidae). Aquaculture, 29:45-52.

Leger, P., D.A. Bengston, K.L. Simpson and P. Sorgeloos, 1986. The use and nutritional value of Artemia as a food source. Oceanography Marine Biology Annual Reviews, 24:521-623.

Leger, P. and P. Sorgeloos, 1992. Optimized feeding regimes in shrimp hatcheries, p.225-244. In: A.W. Fast and L.J. Lester (eds.). Marine shrimp culture: principles and practices. Developments in Aquaculture and Fisheries Science Series No. 23. Elsevier Science Publishing, Amsterdam, the Netherlands.

Lewis, S., R. Gorden, H. Buck, P. Brown, M. Gould and L. Dexter, 1988. Microbiologically modified alkaline hydrogen peroxide-treated straws as a feed for crayfish. Program Abstracts of the 19th Annual Meeting of the World Aquaculture Society. Journal of the World Aquaculture Society, 19(1).

Liao, I.-C. and N.-H. Chao, 1982. Progress of Macrobrachium farming and its extension in Taiwan, p.357-379. In M.B.New, (ed.). Giant prawn farming. Elsevier (Publishers) Ltd, Amsterdam, Holland.

Lilyestrom, C.G., R.P. Romaire and P. Aharon, 1987. Diet and food assimilation by channel catfish and Malaysian prawns in polyculture as determined by stomach content analysis and stable carbon isotope ratios. Journal of the World Aquaculture Society, 18(4):278-288.

Lim, C., 1993. Effect of dietary Ph on amino acid utilization by shrimp (Penaeus vannamei). Aquaculture, 114:293-303.

Lim, C. and W. Dominy, 1990. Evaluation of soybean meal as a replacement for marine animal protein in diets for shrimp. Aquaculture, 87:53-63.

Lim, C. and W. Dominy, 1992. Substitution of full-fat soybeans for commercial soybean meal in diets for shrimp, Penaeus vannamei. Journal of Applied Aquaculture, 1(3):35-45.

Lim, C. and A. Persyn, 1989. Practical feeding: penaeid shrimps, p.205-222. In R.T. Lovell (ed.). Nutrition and feeding of fish. Van Nostrand Reinhold (Publishers), New York, USA.

Lin, C.S., B.G. Chang, M.S. Su and K. Shitanda, 1981. Requirement of white fish meal protein in diet of grass shrimp, Penaeus monodon. China Fisheries Monograph, 337:13-15 (In chinese).

Ling, S.W., 1969. The general biology and development of Macrobrachium rosenbergii. FAO Fisheries Report, 3:589-606.

Liong, P.C., H.B. Hanafi, Z.O. Merican and G. Nagaraj, 1988. Aquaculture development in Malaysia, p.73-90. In J.V.Juario and L.V.Benitez (eds.) Perspectives in Aquaculture Development

in Southeast Asia and Japan. Proceedings of the Seminar on Aquaculture Development in Southeast Asia, Iloilo City, Philippines, 8-12 September 1987.

Lochmann, R., W.R. McClain and D.M. Gatlin, 1992. Evaluation of practical feed formulations and dietary supplements for red swamp crayfish. Journal of the World Aquaculture Society, 23(3):217-227.

Luis, O.J. and I. Batista, 1990. The influence of protein quality and lipid composition from two Portuguese fishmeals on growth of early juveniles of Palaemon Serratus (Crustacea, Decapoda). Biological Institute for National Fisheries Investigation of Portugal, 15:5-14.

Lytle, J.S., T.F. Lytle and J.T. Ogle, 1988. Polyunsaturated fatty acids in the diet of Penaeus vannamei. Program Abstracts of the 19th Annual Meeting of the World Aquaculture Society. Journal of the World Aquaculture Society 19(1).

Maclean, M.H., K.J. Ang, J.H. Brown and K. Jauncey, 1989. The effect of organic fertilizer and formulated feed in pond culture of the freshwater prawn, Macrobrachium rosenbergii (de Man): prawn production. Aquaculture and Fisheries Management, 20:399-406.

Makinouchi, S. and J.H. Primavera, 1987. Maturation and spawning of Penaeus indicus using different ablation methods. Aquaculture, 62:73-81.

Manik, R., 1976. Preliminary studies on the effect of different pelleted formulated feeds on the growth of Macrobrachium rosenbergii. Bulletin of the Shrimp Culture Research Centre in Jepara (Indonesia), II:187-193.

Manik, R., 1980. Formulated feeds for freshwater prawn Macrobrachium rosenbergii, p. 65-81. In V.Soesanto, S.Adisukresno and G.L.Escritor (editors) Report of the Training Course on Prawn Farming for Asia and the Pacific, Jepara (Indonesia), 5 October to 15 November 1980. FAO Field Document, South China Sea Fisheries Development and Coordinating Programme, Workshop report SCS/GEN/81/28, Manila, Philippines.

Manik, R., I.S. Djunaidah and B. Tiensongrusmee, 1980. The survival and growth of postlarval shrimp, Penaeus monodon, reared in laboratory with formulated feed. Bulletin of the Brackishwater Aquaculture Development Centre in Jepara (Indonesia), 6:422-427.

Marchiori, M., C.V. Magalhaes, J.S. Yunes and J.A. Levy, 1982. Studies on artificial feeding of Penaeus paulensis. Atlantica, 5(1):43-48 (In Portuguese).

Marte, C., 1982. Seasonal variation in food and feeding of Penaeus monodon Fabricus (Decapoda, Natantia). Crustaceana, 42(3):250-255.

Maugle, P. D., O. Deshimaru, T. Katayama and K. L. Simpson, 1982. Effect of short-necked clam diets on shrimp growth and digestive enzyme activities. Bulletin of the Japanese Society of Scientific Fisheries, 48(12):1759-1764.

McClain, W.R., W.H. Neill and D.M. Gatlin, 1992. Nutrient profiles of green and decomposed rice-forages and their utilization by juvenile crayfish (Procambarus clarkii). Aquaculture, 101:251-265.

McClain, W. R., W. H. Neill and D. M. Gatlin, 1992a. Partitioning the contributions of forage based production system components to weight gain of juvenile crayfish (Procambarus clarkii). Aquaculture, 101:267-281.

Mervane, Z., J. and M. Rivera P., 1992. Maturation, fertilization and larval culture of Penaeus vannamei in Chile. World Aquaculture, 23(4):58-59.

Merrick, J.R. and C.N. Lambert., 1991. The yabby, marron and red claw: production and marketing. Macarthur Press Pty. Ltd., Parramatta, Australia, 180p.

Meyers, S.P., 1986. Utilization of shrimp processing wastes. Infofish Marketing Digest, 4/86:18-19.

Meyers, S.P., 1988. Development of coastal aquaculture: A report prepared for the Government of India for Brackish Water Aquaculture Program. Rome (Italy). 35 p. FAO Field Document, FAO Project: IND/85/059 - Development of Coastal Aquaculture.

Meyers, S.P., 1989. Squid protein and soy lecithin as beneficial additives in shrimp diets. Infofish International, 2/89:22.

Middleditch, B., S. Missler, H. Hines, E. Chang, J. McVey, A. Brown and A. Lawrence, 1980. Maturation of penaeid shrimp: lipids in the marine food web. Proceedings of the World Mariculture Society, 11:463-470.

Millamena, O.M., J.H. Primavera, R.A. Pudadera and R.V. Caballero, 1986. The effect of diet on the reproductive performance of pond-reared Penaeus monodon Fabricus broodstock, p.593-596. In J.L.Maclean, L.B.Dizon and L.V.Hosillos (editors) The First Asian Fisheries Forum. The Asian Fisheries Society, Manila, Philippines.

Miltner, M., S. Cange, W. G. Perry and J. W. Avault. 1983. Rice straw as a feed supplement for Macrobrachium rosenbergii in ponds. Journal of the World Aquaculture Society, 14:170-173.

Mito, S. and O. Fukuhara, 1988. Aquaculture development in Japan, p.39-72. In J.V.Juario and L.V.Benitez (eds.). Perspectives in Aquaculture Development in Southeast Asia and Japan. Proceedings of the Seminar on Aquaculture Development in Southeast Asia, Iloilo City, Philippines, 8-12 September 1987.

Mohanakumaran Nair, C. and P.M. Sherief, 1992. Effects of diets containing different proportions of clam meat and tapioca on growth of Macrobrachium rosenbergii. In National Seminar on Prawn Feeds and National Workshop on the Impact of Coastal Aquaculture on Environment, 25-26 February 1992, The Fisheries College and Research Institute (Tuticorin) and The Asian Fisheries Society (Indian Branch) Souvenir (Abstract).

Moore, L.B. and R.W. Stanley, 1982. Corn silage as a feed supplement for grow-out of Macrobrachium rosenbergii in ponds. Journal of the World Mariculture Society, 13:86-94.

Moriarty, D.J.W., Cook, H.L., Hassan, R., Thanabal, M., 1984. The contribution of primary production and meiofauna to food chains based on bacteria in penaeid prawn aquaculture ponds, p.161-181. In Coastal aquaculture development, Malaysia. Rome (Italy). FAO Field Document, FAO Project: MAL/77/008 - Coastal Aquaculture Demonstration and Training. FAO Field Document 2.

Moss, S.M., G.D. Pruder, K.M. Leber and J.A. Wyban, 1992. The relative enhancement of Penaeus vannamei growth by selected fractions of shrimp pond water. Aquaculture, 101:229-239.

Mossmann, S.M., B. Maraes, D.R. Azevedo, G.F. Rey, I.P Silveira, M. Frozza, P.K. Serdiuk and T.M. Azevedo-Viana, 1990. Growth of Macrobrachium rosenbergii fed with an alternative diet. Estudios Leopold, 26(118):13-26 (In Portuguese).

Motoh, H., 1984. Biology and ecology of Penaeus monodon, p.27-36. In Proceedings of the First International Conference on the Culture of Penaeid Prawns/Shrimps, Iloilo City, Philippines.

Murai, T., A. Somalangcay and F. Piedad-Pascaal, 1983. Supplement of various attractants to a practical diet for juvenile Penaeus monodon (Fabricus). Fisheries Research Journal of the Philippines, 8(2):61-67.

Murthy, D.K. and K.V. Rajagopal, 1990. Food and feeding habits of the freshwater prawn, Macrobrachium equidens (Dana). Indian Journal of Animal Sciences, 60(1):118-122.

Muthu, M.S., 1983. Penaeid broodstock development and management. Paper presented at the National Symposium on Shrimp Seed Production and Hatchery Management, 21-22 January 1983, Cochin, India, 31p.

Nascimento, I.A., W.A. Bray, J.R. Leung Trujillo and A. Lawrence, 1991. Reproduction of ablated and unablated Penaeus schmitti in captivity using diets consisting of fresh-frozen natural and dried formulated feeds. Aquaculture, 99:387-398.

Natarajan, M.V., I. Nalluchinnappan, G. Rajappan and S.M. Mohamed Ali, 1987. Cage rearing of early juveniles of white prawn Penaeus indicus (H. Milne Edwards) for stocking in grow out net pens. Journal of the Marine Biological Association of India, 29(1 & 2):387-390.

New, M.B. and S. Singholka, 1982. Freshwater prawn farming: a manual for the culture of Macrobrachium rosenbergii. Rome, FAO, FAO Fisheries Technical Paper (225) Rev.1:118p.

Ogle, J.T., 1991. Maturation of Penaeus vannamei based upon a survey. Gulf Research Reports, 8(3):295-297.

Ogle, J.T. and K. Beaugez., 1991. Food preference of Penaeus vannamei. Gulf Research Reports, 8(3):291-294.

Omara-Alwala, T.R. and D.E. Prior, 1991. Essentiality of supplemental feeding in freshwater shrimp culture under evacuated fish pond conditions. World Aquaculture Society Program Abstracts, June 16-20 1991, Puerto Rico.

Ostrowski-Meissner, H.T., E.O. Dueer and L. Vannatta, 1992. The effect of ingredient grind on juvenile shrimp (Penaeus vannamei) growth, feed conversion, and survival, p.177-178. In Aquaculture '92, Growing toward the 21st Century. 21-25 May 1992, Orlando, Florida (USA)

Palaniswamy, R. and S. Ahmad Ali, 1991. The impact of particle size of ingredients in compound diets on pellet stability and performance in Penaeus indicus H.Milne Edwards. Journal of Aquaculture in the Tropics, 6:119-127.

Pascual, F.P., 1985. Earthworm, marine annelids and squid as feed ingredients in formulated diets for juvenile Penaeus monodon, p.182. In Y. Taki, J.H. Primavera, J.A. Lobrera (eds). Proceedings of the First International Conference on the Culture of Penaeid prawns/shrimps. Iloilo City (Philippines), 4-7 December 1984. SEAFDEC, Manila, Philippines.

Pascual, F.P., 1989. Formulated feeds of Penaeus monodon. Report of the Workshop on Shrimp and Finfish Feed Development, Johore Bahru (Malaysia), 25-29 October 1988. Manila (Philippines), p.35-44. FAO Project:RAS/84/016 - ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project. Working Paper ASEAN/SF/89/GEN/11.

Pascual, F.P. and M. Catacutan, 1990. Defatted soybean meal and Leucaena leaf meal as protein sources in diets for Penaeus monodon juveniles, p.345-348. In R.Hirano and I.Hanyu, (eds.). The Second Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines.

Pascual, F.P. and W.H. Destajo, 1978. Growth and survival of Penaeus monodon postlarvae fed shrimp head meal as primary animal source of protein. South-east Asian Fisheries Development Centre Quarterly Research Report, 2(1):26-30.

Pascual, F.P., E.M. Cruz and A. Sumalangcay, 1990. Supplemental feeding of Penaeus monodon juveniles with diets containing various levels of defatted soybean meal. Aquaculture, 89:183-191.

Penaflorida, V.D., 1989. An evaluation of indigenous protein sources as potential components in the diet formulation for tiger prawn, Penaeus monodon, using essential amino acid index (EAAI). Aquaculture, 83:319-330.

Penaflorida, V.., F.P. Pascual and N.S. Tabbu, 1992. A practical method of extracting mimosine from ipil-ipil, Leucaena leucocephala, leaves and its effect on survival and growth of Penaeus monodon juveniles. Bamidgeh, 44(1):24-31.

Pike, I.H. 1991, Increasing importance of aquaculture to the fish meal industry - estimated sales of fish meal and oil to aquaculture in 1990 over one million tonnes. IAFMN (International Association of Fish Meal Manufacturers). Technical Market Report, April 1991, Potters Bar, England, UK. 5p.

Pollock, D.E., 1979. Predator-prey relationships between the rock lobster Jasus lalandii and the mussel Aulacomya ater at Robben Island on the Cape west coast of Africa. Marine Biology, 52(4):347-356.

Primavera, J.E. and R.Q. Gacutan, 1989. Preliminary results of feeding aquatic macrophytes to Penaeus monodon juveniles. Aquaculture, 80:189-193.

Prinpanapong, S. and T. Youngwanichsaed, 1992. Rearing of mud crab (Scylla serrata), p. 191-194. In C.A. Angell (ed.). Report of the seminar on the mud crab culture and trade held in Thailand, Nov. 5-8 1991, Bay of Bengal Programme. Report No. BOBP/REP/51. Project GCP/RAS/118/MUL, Madras, India, 246 p.

Provanzano, A.J., 1985. Commercial culture of decapod crustaceans, p.269-314. In A.J.Provenzano, (ed.). The Biology of Crustacea, Volume 10 Economic Aspects: Fisheries and Culture. Academic Press, London and New York.

Quackenbush, L.S. and W.F. Herrnkind, 1981. Regulation of molt and gonadal development in the spiny lobster, Panulirus argus (Crustaceana: Palinuridae): effect of eyestalk ablation. Comparative Biochemistry and Physiology, 69A:523-527.

Rajyalakshmi, T., S.M. Pillai, A.K. Roy and P.U. Verghese, 1986. Feeds and nutrition of the prawn Penaeus monodon. Environment and Ecology, 4(3):415-422.

Raman, K., S. Srinivasagam and S. Krishnan, 1980. Preliminary studies on culture of portunid crabs, Scylla serrata and Portunus pelagicus. Proceedings of the Symposium on Inland Aquaculture, Central Inland Fisheries Research Institute (CIFRI), Barrackpore, Abs. No. 111.

Ravishankar, A.N. and P. Keshavanath, 1988. Utilization of artificial feeds by Macrobrachium rosenbergii (De Man). Indian Journal of Animal Science, 58(7):876-881.

Reigh, R.C., S.L. Braden and R.J. Craig, 1990. Apparent digestibility coefficients for common feedstuffs in formulated diets for red swamp crayfish, Procambarus clarkii. Aquaculture, 84:321-334.

Reymond, H. and J.P. Lagardere, 1990. Feeding rhythms and food of Penaeus japonicus Bate (Crustacea, Penaeidae) in salt marsh ponds: role of halophilic entomofauna. Aquaculture, 84:125-143.

Ricque, D., L.E. Cruz-Suarez and P. Espinoza-Gonzalez, 1991. Nutritional evaluation of the baker's or brewer's yeast Saccharomyces cerevisiae as protein sources for Penaeus vannamei feed. World Aquaculture Society Program Abstracts, June 16-20 1991, Puerto Rico.

Robinson, E.H., 1989. Practical feeding: crawfish, p. 231-241. In R.T. Lovell (ed.) Nutrition and feeding of fish. Van Nostrand Reinhold (Publishers), New York, USA.

Roques, C. and L. Dussert, 1991. The interest of live yeast supplementation in aquaculture and its improving effect on feed conversion. European Aquaculture Society Special Publication No.14:280-281.

Rosenberry, R. (ed.), 1992. World shrimp farming 1992. Aquaculture Digest (Publishers), San Diego, USA, November 1, 1992. 45p.

Rubright, J.S., J.L. Harrell, H.W. Holcomb and J.C. Parker, 1981. Responses of planktonic and benthic communities to fertilizer and feed applications in shrimp mariculture ponds. Journal of the World Mariculture Society, 12(1):281-299.

Sanguanruang, M. and R.P. Romaire, 1988. Assimilation efficiency and growth of juvenile red swamp and white river crawfish fed various diets. Program Abstracts of the 19th Annual Meeting of the World Aquaculture Society. Journal of the World Aquaculture Society, 19(1).

Sarac, Z., H. Thaggard, J. Saunders, M. Gravel, A. Neill and R.T. Cowan, 1993. Observations on the chemical composition of some commercial prawn feeds and associated growth responses in Penaeus monodon. Aquaculture, 115:97-110.

Sedgwick, R.W., 1980. The requirements of Penaeus merguiensis for vitamin and mineral supplements in diets based on freeze-dried Mytilus edulis meal. Aquaculture, 19:127-137.

Shang, Y.C., 1989. Marine shrimp farming in PR China. Infofish International, 2/89:16-17.

Sheen, S-S. and J-C. Chen, 1991. Growout study for Penaeus monodon with different diets containing extruded rice and wheat flour. World Aquaculture Society Program Abstracts, June 16-20 1991, Puerto Rico.

Shiau, S.-Y. and B.-S. Chou, 1991. Effects of dietary protein and energy on growth performance of Tiger shrimp Penaeus monodon reared in seawater. Nippon Suisan Gakkaishi, 57 (12):2271-2276.

Shiau, S.-Y., S.-F. Lin and L.-J. Lu, 1991. Effects of different types of wheat flour in feed for grass prawn Penaeus monodon. Nippon Suisan Gakkaishi, 57(4):705-710.

Smallridge, M., R. Musgrove, S. Allenson and S. Clarke, 1989. Growth of juvenile yabbies fed on live food. Safish, 14(2):6-8.

Solis, N. B., 1988. Farming of tiger prawn in the Philippines. South-east Asian Fisheries Development Centre Newsletter, 11(4):6-13.

Sommer, T.R., N.M. Morrissy and W.T. Potts, 1991. Growth and pigmentation of marron (Cherax tenuimanus) fed a reference ration supplemented with the microalga Dunaliella salina. Aquaculture, 99:285-295.

Sorgeloos, P., E. Bossuyt, P. Lavens, P. Leger, P. Vanhaecke and D. Versichele, 1983. The use of brine shrimp Artemia in crustacean hatcheries and nurseries, p.71-96. In J.P.McVey (ed.). Handbook of Mariculture, Volume 1, CRC Press, Boca Raton, USA.

Srinivasagam, S., and M. Kathirvel, 1992. A review of experimental culture of the mud crab, Scylla serrata (Forskal) in India, p.195-206. In C.A. Angell (ed.). Report of the seminar on the mud crab culture and trade held in Thailand, Nov. 5-8 1991, Bay of Bengal Programme. Report No. BOBP/REP/51. Project GCP/RAS/118/MUL, Madras, India, 246 p.

Sriraman, K. and R. Anantha Narayanan, 1987. Culture of Penaeus indicus (Milne-Edwards) with different stocking densities. Journal of the Marine Biological Association of India, 29(1 & 2):108-114.

Stanely, R.W. and L.B. Moore, 1983. The growth of Macrobrachium rosenbergii fed commercial feeds in pond cages. Journal of the World Mariculture Society, 14:174-184.

Stern, H.L., D.A. Armstrong, A.W. Knight and D.J. Chippendale, 1976. Survival and growth of the giant malaysian prawn, Macrobrachium rosenbergii, fed natural plant diets, p.667-671. In Proceedings of the 7th Annual Workshop of the World Mariculture Society, San Diego, California, 25-29 January 1976, Louisiana State University, Baton Rouge, USA.

Subosa, P.F., 1992. Chicken manure, rice hulls, and sugar mill wastes as potential organic fertilizers in shrimp (Penaeus monodon Fabricus) ponds. Aquaculture, 102:95-103.

Sumeru, S.U., 1989. Status of shrimp feed development at BADC, Jepara, Indonesia. Report of the Workshop on Shrimp and Finfish Feed Development, Johore Bahru (Malaysia), 25-29 October 1988. Manila (Philippines), p.45-52. FAO Project: RAS/84/016 - ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project. Workshop Report ASEAN/SF/89/GEN/11.

Syslo, M. and J.T. Hughes, 1981. Vegetable matter in lobster (Homarus americanus) diets (Decapoda, Astacidea). Crustaceana, 41(1):10-13.

Tacon, A.G.J., 1986. Larval shrimp feeding - Crustacean tissue suspension: A practical alternative for shrimp culture. FAO Field Document No.ADCP/MR/86/23, Rome, Italy, 31p.

Tacon, A.G.J., 1987. The nutrition and feeding of farmed fish and shrimp - A training manual. 2. Nutrient sources and composition. FAO Field Document, Project GCP/RLA/075/ITA, Field Document No.2, Brasilia, Brazil, 129p.

Tacon, A.G.J., 1988. The nutrition and feeding of farmed fish and shrimp - A training manual. 3. Feeding methods. FAO Field Document, Project GCP/RLA/075/ITA, Field Document No.7, Brasilia, Brazil, 208p.

Tacon, A.G.J., 1992. Feed formulation and on-farm feed management. Paper presented at the FAO/AADCP Expert Consultation on farm-made aquafeeds, 14-18 December 1992, Bangkok, Thailand (In Press).

Tacon, A.G.J., 1993. Feed ingredients for warmwater fish: fish meal and other processed feedstuffs. FAO Fisheries Circular No. 856. Rome, FAO, 64p.

Tacon, A.G.J., 1993a. Application of nutrient requirement data under practical conditions: special problems of intensive and semi-intensive fish farming systems. Paper presented at the EIFAC Workshop on Methodology for Determination of Nutrient Requirements in Fish, 29 June to 1 July 1993, Eichenau, Germany (In Press).

Tacon, A.G.J. and A.J. Jackson, 1985. Utilisation of conventional and unconventional protein sources in practical fish feeds, p.119-145. In C.B.Cowey, A.M.Mackie and J.G.Bell (eds.). Nutrition and feeding in fish, Academic Press, London and New York.

Teichert-Coddington, D.R., B.W. Green and R.W. Parkman, 1991. Substitution of chicken litter for feed in production of penaeid shrimp in Honduras. Progressive Fish Culturist, 53:150-156.

Teshima, S., A. Kanazawa, S. Koshio and K. Horinouchi, 1988. Lipid metabolism in destalked prawn Penaeus japonicus: Induced maturation and accumulation of lipids in the ovaries. Nippon Suisan Gakkaishi, 54(7):1115-1122.

Teshima, S.-I., A. Kanazawa, M.-Yamashita and S. Koshio, 1991. Rearing of larval prawn Penaeus japonicus with brown fish meal based diets. Nippon Suisan Gakkaishi, 57(1):175.

Thong, P.Y., 1985. Least-cost formulation of feeds for prawns, with particular reference to Macrobrachium rosenbergii (de Man). M.Sc thesis, Universiti Pertanian Malaysia, Malaysia, 156p.

Tidwell, J.H., C.D. Webster, J.A. Clark and L.R. D'Abramo, 1993. Evaluation of distiller dried grains with solubles as an ingredient in diets for pond culture of the freshwater prawn Macrobrachium rosenbergii. Journal of the World Aquaculture Society, 24(1):66-70.

Tinsley, A.M., N.L. Soifer, J.M. Kern and C.W. Weber, 1984. Housefly meal as a protein source for controlled environment aquaculture shrimp. Nutrition Reports International, 29(2):405-410.

Trino, A.T. and M.E.C. Bolivar, 1990. Growth performance of Penaeus monodon in Lablab, Lumut, and Digman ponds under various farm practices. Journal of Aquaculture in the Tropics, 5:123-129.

Trino, A.T., V.D. Penaflorida and E.C. Bolivar, 1992. Growth and survival of Penaeus monodon juveniles fed a diet lacking vitamin supplements in a modified extensive culture system. Aquaculture, 100:25-32.

Ung, E.H., Junilla, M., 1989. Preliminary observations on the nutritional effects of a betaine/amino acid mixture: survival, growth and food conversion of juvenile Penaeus monodon fed with Finnstim, p.71-84. Workshop on Shrimp and Finfish Feed Development. Manila (Philippines). FAO Project: RAS/84/016 - ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project. Workshop Report ASEAN/SF/89/GEN/11.

Unprasert, N., 1989. Country paper (Thailand): Fish feeds and feedstuffs used for aquaculture in Thailand, p.147-155. Report of the Workshop on Shrimp and Finfish Feed Development, Johore Bahru (Malaysia), 25-29 October 1988. Manila (Philippines). FAO Project: RAS/84/016 - ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project. Workshop Report ASEAN/SF/89/GEN/11.

Venkataramiah, A., G.J. Lakshmi and G. Gunter, 1975. Effect of protein level and vegetable matter on growth and food conversion efficiency of brown shrimp. Aquaculture, 6:115-125.

Vijayakumaran, M. and E.V. Radhakrishnan, 1984. Effect of eyestalk ablation in the spiny lobster Panulirushomarus (Linnaeus): 2. On food intake and conversion. Indian Journal of Fisheries, 31(1):151-155.

Vijayaraghavan, S. and S. Wafar, 1983. Further studies in using mangrove foliage as a prawn feed. Mahasagar Bulletin of the National Institute of Oceanography, 16(3):309-316.

Villarreal, H., 1991. A partial energy budget for the Australian crayfish Cherax tenvimanus. Journal of the World Aquaculture Society, 22(4):252-259.

Villarreal, H., M.C. Rivera and A. Millan, 1991. Effect of the substitution of shrimp meal, fish meal and soy meal for red crab (Pleuroncodes planipes) meal in the growth of juvenile Penaeus californiensis. World Aquaculture Society Program Abstracts, June 16-20, 1991, Puerto Rico.

Visscher, P.T. and E.O. Duerr, 1991. Water quality and microbial dynamics in shrimp ponds receiving bagasse-based feed. Journal of the World Aquaculture Society, 22(1):65-76.

Visscher, P.T., K.M. Leber and S. Moss, 1988. Shrimp foraging effects upon microbial communities in experimental microcosms. Program Abstracts of the 19th Annual Meeting of the World Aquaculture Society. Journal of the World Aquaculture Society, 19(1).

Vogt, G., E.T. Quinitio and F.P. Pascual, 1986. Leucaena leucocephala leaves in formulated feed for Penaeus monodon: a concrete example of the application of histology in nutrition research. Aquaculture, 59:209-231.

Warner, G.F., 1977. The biology of crabs. Paul Elek (Scientific Books) Ltd., London.

Wassenberg, T.J. and B.J. Hill, 1987. Natural diet of the tiger prawns Penaeus esculentus and P. semisulcatus. Australian Journal of Marine and Freshwater Research, 38:169-182.

Wassenberg, T.J., and B.J. Hill, 1993. Diet and feeding behaviour of juvenile and adult banana prawns Penaeus merguiensis in the Gulf of Carpentana, Australia. Marine Ecology Progress Series, 94:287-295.

Weidenbach, R.P., 1982. Dietary components of freshwater prawns reared in Hawaiin ponds, p.257-267. In M.B.New, (ed.). Giant Prawn Farming. Elsevier Press Ltd, Amsterdam, Holland.

Wickens, J.F., 1976. Prawn biology and culture. Marine Biology Annual Reviews, 14:435-507.

Wickens, J.F. and T.W. Beard, 1974. Observations on the breeding and growth of the giant freshwater prawn Macrobrachium rosenbergii (De Man) in the laboratory. Aquaculture, 3:159-174.

Wood, J. and J.H. Brown, 1990. Making high quality shrimp feed in India: What do initial trials show? Bay of Bengal News No.39:14-17.

Wood, J. and J. Coulter, 1988. India's expanding prawn culture industry: where will the feed materials come from? Bay of Bengal News No. 32:12-18.

Wood, J.F., J.H. Brown, M.H. MacLean and I. Rajendran, 1992. Feeds for artisanal shrimp culture in India. Their development and evaluation. Bay of Bengal Programme, Report No. BOBP/REP/52, Madras, India, 59 p.

Yano, I., 1984. Induction of rapid spawning in kuruma prawn, Penaeus japonicus, through unilateral eyestalk enucleation. Aquaculture, 40:265-268.

Yano, I., 1985. Induced ovarian maturation and spawning in greasyback shrimp, Metapenaeus ensis, by progesterone. Aquaculture, 47:223-229.

Yano, I., B. Tsukimura, J.N. Sweeney and J.A. Wyban, 1988. Induced ovarian maturation of Penaeus vannamei by implantation of lobster ganglion. Journal of the World Aquaculture Society, 19(4):204-209.

Zein-Eldin, Z.P. and J. Corliss, 1976. The effect of protein levels and sources on growth of Penaeus aztecus, p. 592-597. In T.V.R.Pillay and W.A.Dill (editors) Advances in Aquaculture. Fishing News (Books) Ltd for FAO, Farnham, England.

Zhang, S., 1992. Studies on the prawn's digestive rate of the feed added with the diet yeast instead of pen fishmeal. Shandong Fisheries Qilu Yuye (Peoples Republic of China), 5:32-34.

Zimmermann, S. and D. Cohen, 1991. Testing five levels of dry sugar cane yeast in feeds for freshwater prawns, Macrobrachium rosenbergii (de Man), reared in nursery. World Aquaculture Society Program Abstracts, June 16-20 1991, Puerto Rico.

Zoutendyk, P., 1988. Feeding, defaecation and absorption efficiency in the Cape Rock Lobster Jasus lalandii. South African Journal of Marine Science, 6:59-65.

Table 1. 1991 world crustacean aquaculture production by species group 1/

1991 WORLD AQUACULTURE PRODUCTION OF CRUSTACEANS	
CRUSTACEAN SPECIES GROUP	PRODUCTION (t)
TOTAL CRUSTACEANS	806,260
Freshwater crustaceans	
Red swamp crawfish (Procambarus clarkii)	30,181
Giant river prawn Macrobrachium rosenbergii)	26,290
Other freshwater crustacea (spp not given)	7,007
Yabby crayfish (Cherax destructor)	87
Red claw crayfish (Cherax quadricarinatus)	33
Other crayfishes (Astacus sp, Cambarus spp)	28
Marron crayfish (Cherax tenuimanus)	15
Group total	**63,641**
Sea-spiders, crabs	
Chinese river crab (Eriocheir sinensis)	5,000
Mud crab (Scylla serrata)	4,465
Other marine crabs (Reptantia; sp not given)	75
Swimcrabs (Portunus spp)	10
Spinous spider crab (Maja squinado)	8
Group total	**9,558**
Lobsters, spiny-rock lobsters	
Longlegged spiny lobster (Panulirus longipes)	51
Other tropical spiny lobsters (Panulirus spp)	40
Palinurid spiny lobsters (Palinurus spp)	33
Group total	**124**
Shrimps, prawns	
Giant tiger prawn (Penaeus monodon)	245,361
Fleshy prawn (Penaeus chinensis)	187,465
Whiteleg shrimp (Penaeus vannamei)	115,098
Penaeid shrimp (Penaeus spp, spp not given)	49,857
Natantian decapods (Natantia)	46,615
Banana prawn (Penaeus merguiensis)	27,455
Metapenaeid shrimp (Metapenaeus spp)	24,712
Kuruma prawn (Penaeus japonicus)	14,046
Indian white prawn (Penaeus indicus)	4,249
Blue shrimp (Penaeus stylirostris)	1,610
Akiami paste shrimp (Acetes japonicus)	1,500
Redtail prawn (Penaeus penicillatus)	877
Atlantic seabob (Xiphopenaeus kroyeri)	50
Eastern school shrimp (Metapenaeus macleayi)	2
Group total	**718,897**
Miscellaneous marine crustaceans	
Marine crustacea (species not given)	14,037
Brine shrimp (Artemia salina)	3
Group total	**14,040**

1/ FAO (1993)

Table 2. Contribution of aquaculture to world fishery production 1/

AQUACULTURE CONTRIBUTION TO WORLD FISHERY PRODUCTION 1985-1991
(values given in '000 mt)

	1985	1986	1987	1988	1989	1990	1991
WORLD CATCH AND CULTURE OF FISH AND SHELLFISH	86,324	92,803	94,379	99,016	100,208	97,433	96,926
TOTAL CATCH	78,598	84,001	84,234	87,817	88,775	85,331	84,251
TOTAL CULTURED	7,726	8,802	10,145	11,199	11,433	12,102	12,675
- % total	8.9%	9.5%	10.7%	11.3%	11.4%	12.4%	13.1%
Total fish landings	75,907	81,809	82,049	86,322	87,084	84,656	83,681
Capture	70,679	75,828	75,191	78,759	79,307	76,318	74,940
Culture	5,228	5,981	6,858	7,563	7,777	8,338	8,741
- % total	6.9%	7.3%	8.4%	8.8%	8.9%	9.8%	10.4%
Freshwater fishes	8,676	9,665	10,403	11,056	11,406	12,118	12,579
- Capture	4,331	4,612	4,578	4,649	4,840	5,191	5,310
- Culture	4,345	5,053	5,825	6,407	6,566	6,927	7,269
- % total	50.0%	52.3%	56.0%	58.0%	57.6%	57.2%	57.8%
Diadromous fishes	2,609	2,538	2,676	2,678	3,050	3,089	3,250
- Capture	1,949	1,844	1,906	1,806	2,120	1,987	2,118
- Culture	660	694	770	872	930	1,102	1,132
- % total	25.3%	27.3%	28.8%	32.6%	30.5%	35.7%	34.8%
Marine fishes	64,622	69,605	68,970	72,588	72,627	69,449	67,852
- Capture	64,400	69,372	68,708	72,304	72,346	69,140	67,512
- Culture	222	233	262	284	281	309	340
- % total	0.3%	0.3%	0.4%	0.4%	0.4%	0.4%	0.5%
Total crustacean landings	3,676	4,086	4,268	4,461	4,601	4,632	4,790
Capture	3,403	3,698	3,680	3,809	3,914	3,879	3,984
Culture	273	388	588	652	687	753	806
- % total	7.4%	9.5%	13.8%	14.6%	14.9%	16.3%	16.8%
Shrimps, prawns	2,133	2,233	2,365	2,497	2,508	2,575	2,647
- Capture	1,915	1,920	1,865	1,921	1,900	1,909	1,928
- Culture	218	313	500	576	608	666	719
- % total	10.2%	14.0%	21.1%	23.1%	24.2%	25.9%	27.2%
Freshwater spp.	182	214	247	231	250	247	263
- Capture	143	156	177	172	192	183	199
- Culture	39	58	70	59	58	64	64
- % total	21.4%	27.1%	28.3%	25.5%	23.2%	25.9%	24.3%
Total mollusc landings	6,440	6,558	7,693	7,950	8,209	7,862	8,114
Capture	4,243	4,154	5,021	5,000	5,289	4,892	5,019
Culture	2,197	2,404	2,672	2,950	2,920	2,970	3,095
- % total	34.1%	36.7%	34.7%	37.1%	35.6%	37.8%	38.1%
Miscellan. aquatic animals	302	351	365	284	314	283	341
Capture	274	321	337	250	265	242	309
Culture	28	30	28	34	49	41	32
- % total	9.3%	8.5%	7.7%	12.0%	15.6%	14.5%	9.4%
WORLD LANDINGS OF AQUATIC PLANTSCapture	3,877	3,863	3,547	4,133	4,376	4,321	4,905
Culture	442	462	523	782	1,076	1,114	1,001
- % total	3,435	3,401	3,024	3,351	3,300	3,207	3,904
	88.6%	88.0%	85.3%	81.1%	75.4%	74.2%	79.6%

1/ FAO (1993, 1993a)

Table 3. Natural food and feeding habits of decapod crustaceans

Marine shrimp (Penaeus sp., Metapenaeus sp.)

Marine shrimp are generally classified as being either omnivorous scavengers or detritus feeders; reported stomach contents for P. esculentus, P. indicus, P. merguiensis, P. monodon, P. semisulcatus, P. setiferus, P. stylirostris and P. vannamei including crustaceans (and other shrimp), annelids (polychaetes), molluscs (bivalves), echinoderms (ophiuroids), nematodes, fish tissue, algae, vegetable matter and detritus (Bombeo-Tuburan, Guanzon & Schroeder, 1993; Bray & Lawrence, 1992; Chong & Sasekumar, 1981; Crockett et al. 1988; Feller, 1991; Lim & Persyn, 1989; Moriarty et al. 1984; Motoh, 1984; Pascual, 1989; Rubright et al. 1981; Trino & Bolivar, 1990; Wassenberg & Hill, 1987, 1993; Wickins, 1976). Although animal protein constitutes the bulk of the diet of these shrimp (Leber et al. 1988; Marte, 1982; Motoh, 1984; Wassenberg & Hill, 1987), some species have developed more carnivorous tendencies than others (ie. P. japonicus and P. esculentus compared with P. monodon (Dall et al. 1991; Hill & Wassenberg, 1987; Reymond & Lagardere, 1990), P. monodon compared with P. merguiensis and P. indicus (personal observation), or P. stylirostris compared with P. vannamei (Garson et al. 1986; Garcia-Casas, 1990), whereas other shrimp species are reported to have more herbivorous feeding habits (ie. Metapenaeus affinis and M. ensis, George, 1972; Wickens, 1976). Despite the above generalizations, it should be pointed out that even predominantly carnivorous shrimp species also consume plant material depending upon food availability and season (ie. ripe seeds of the seagrass Zostera capricorni consumed by P. esculentus (Dall et al. 1992) or the macro alga Enteromorpha sp. consumed by P. monodon (Bray & Lawrence, 1992).

The important role played by naturally available food organisms in the diet of pond cultured shrimp has been shown by the study of Anderson et al. (1987), where natural pond biota accounted for 53-77% of the growth carbon of the cultured shrimp (P. vannamei; stocking density 20/m^2), as compared with 23-47% supplied by the exogenously supplied pelleted shrimp diet. Similarly, the study of Cam et al. (1991) with pond reared P. japonicus (stocking density 20/m^2 PL_{20-22}: 25mg body weight) showed that natural productivity accounted for 86.7, 42.7, 41.7 and 34.4% of the growth carbon of shrimp after 30, 60, 90 and 120-days, respectively; all cultured shrimp being fed a 57.4% protein pellet from day 15 after stocking until the end of the 120-day experiment. Interestingly, the studies of Leber & Pruder (1988) and Moss et al. (1992) have also demonstrated the growth-enhancing effect of unfiltered shrimp pond water on the growth of laboratory reared shrimp; P. vannamei reared in microcosm tanks receiving flow-through pond water and fed artificial diets growing over 50% faster than comparable animals receiving clear well water and fed identical diets.

Freshwater prawn (Macrobrachium sp.)

The giant river prawn M. rosenbergii is generally classified as having a benthophagic omnivorous feeding habit; reported stomach contents including organic detritus , molluscs, adult insects and larvae, crustaceans (including other prawns of the same species), fish, algae, grain, aquatic macrophytes and vegetable matter (Buck et al. 1978; Costa & Wanninayake, 1986; Ling, 1969; Weidenbach, 1982). A similar feeding habit has also been observed for the rough river prawn M. equidens (Murthy & Rajagopal, 1990).

Lilyestrom et al. (1987) investigated the feeding habits of M. rosenbergii in polyculture with channel catfish (Ictalurus punctatus) within earthen ponds in Louisiana (USA) and found that prawns (0.5-1.5/m2 initial stocking density) depend to a greater extent on the autotrophic food web for their diet, and that seston and macrophytes contributed 18-75% of prawn growth and formulated feeds the remainder. They also reported that prawns fed on seston at small sizes (<7g) and consumed more aquatic macrophytes and formulated ration at larger sizes (>7g). Similarly, Weidenbach (1982) observed that artificial diets were readily consumed in pond reared M. rosenbergii together with detritus, macrofauna and limited amounts of macrophytes, but that macrophytes dominated the prawns diet when no formulated feeds

Table 3. contd

were provided. By contrast, Murthy & Rajagopal, 1990) reported M. equidens to have a more predatory feeding habit during its adult phase, preferring diatoms and algae only during its juvenile stages.

Freshwater crayfish (Astacus sp., Oronectes sp., Pacifastacus sp., Procambarus sp.)

Although freshwater crayfish are often classified as detritivores or herbivores, the fact that crayfish (particularly during their larval and juvenile phase) also consume considerable amounts of animal food suggests that an omnivorous feeding habit may be a closer reflection of the polytrophic feeding habit of the crayfish. For example, although detritus, aquatic macrophytes and benthic algae form the bulk of the stomach contents of natural populations of crayfish, reported animal food items consumed have included molluscs, crustaceans (including other crayfish, cladocera and copepods), rotifers, annelids, aquatic insects, fish and amphibian tadpoles (Avault & Brunson, 1990; Brown et al. 1992; Cobb & Wang, 1985; Goddard, 1988; Hessen, 1989; McClain et al. 1992, 1992a; Merrick and Lambert, 1991; Robinson, 1989). Hessen et al. (1989) reported that animal food accounted for about 10-20 percent (by volume) of the food consumed by adults, but that juvenile crayfish had a strong preference for animal protein, and that during certain periods the entire diet of juveniles could consist of benthic zooplankton or insect larvae.

Lobster (Hommarus sp., Nephrops sp., Jasus sp.)

The lobsters are generally classified as having benthophagic omnivorous feeding habits, although showing preference for animal food and having predatory tendencies; reported stomach contents including other crustacea (crabs and other lobsters), polychaetes, molluscs (bivalves and gastropods), echinoderms (sea urchins and starfish), coelenterates, fish, and vegetable matter (seaweeds: Cobb & Wang, 1985; Conklin, 1980; Evans & Mann, 1977; Herrick, 1909; Syslo & Hughes, 1981: Zoutendyk, 1988). Interestingly, Pollock (1979) reported that mussels were a major component of the diet of the Cape rock lobster (Jasus lalandii) on the west coast of Africa; 97 percent of the stomachs of the wild lobster population containing these bivalves. By contrast, Herrick (1909) reported that 35% of the stomachs of a wild population of the American lobster contained seaweeds, and that the quantities present were only exceeded by ingested fish, crustaceans and molluscs.

Crab (Carcinus sp., Cancer sp., Callinectes sp., Scylla sp.)

Although the large majority of crab species are reported to have benthophagic omnivorous feeding habits, most species of commercial interest (ie. Portunidae, Cancridae, Xanthidae) are carnivores or predators; the reported stomach contents of the above mentioned carnivorous crabs including molluscs (bivalves and gastropods), annelids, crustaceans (including other crabs), fish, echinoderms (starfish, sea urchins, brittle stars and sea cucumbers), and to a lesser extent algae and vascular plants (Hill, 1976; Jayamanne, 1992; Kathirvel & Srinivasagam, 1992; Srinivasagam & Kathirvel, 1992; Provenzano, 1985; Warner, 1977). However, it should also be mentioned that some crab species have developed specialized feeding habits as filter or suspension feeders, detritus or deposit feeders, and as herbivores (for review see Warner, 1977).

Table 4. Major natural feed ingredients employed as complete or supplementary feed for decapod postlarvae

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CRUSTACEANS

1. **Brine shrimp (Artemia salina)**
   Shrimp (P. vannamei/P. semisulcatus/P .monodon) - Browdy et al. (1989), Chen & Lin (1992), Ogle & Beaugez (1991)
   Crayfish (A. astacus) - Hessen (1989)
   Lobster (H. americanus)-Conklin & Chang (1983); Syslo & Hughes (1981)

2. **Krill (Euphausia superba)**
   Shrimp (P. vannamei/japonicus) - Ogle & Beaugez (1991), Mito & Fukuhara (1988), Yano (1984, 1985)

3. **Sergestid shrimp (Acetes indicus & Acetes sp.)**
   Shrimp (P. monodon) - Chiang & Liao (1985), Chuang (1990), Hameed Ali & Dwivedi (1977)

4. **Mysid shrimp (Neomysis integer)**
   Crayfish (A. astacus) - Ackefors et al. (1989)

5. **Mysid shrimp (general)**
   Shrimp (general) - Chamberlain (1991)

6. **Penaeid shrimp (P. aztecus)**
   Shrimp (P. vannamei/P. stylirostris) - Chamberlain & Lawrence (1981)

7. **Penaeid shrimp (general)**
   Shrimp (P. schmitti/P. monodon/P. indicus) - Nascimento et al. (1991), Avalle:personal communication
   Prawn (M. rosenbergii) - Liao & Chao (1982)
   Crab (S. serrata) - Angell (1992)

8. **Common shrimp (Crangon vulgaris)**
   Shrimp (Palaemon serratus/P. merguiensis/P. monodon/P. orientalis) - Arnstein & Beard (1975), Beard et al. (1977), Beard & Wickens (1980), Forster & Beard (1973)
   Prawn (M. rosenbergii) - Wickens & Beard (1974)

9. **Shore crab (Carcinus maenus)**
   Shrimp (Palaemon serratus) - Forster & Beard (1973) 1/

10. **Mud crab (Scylla serrata)**
    Shrimp (P. monodon/P. indicus) - Avalle:personal communication (May 1992, Madagascar)

11. **Crab (Liocarcinus depurator)**
    Shrimp (P. japonicus) - Cruz et al. (1990)

12. **Fiddler crab (Uca pugilator)**
    Lobster (Panulirus argus) - Quackenbush & Herrnkind (1981)

13. **Rock crab (Cancer irroratus)**
    Lobster (H. americanus) - Evans & Mann (1977)

14. **Water flea (Daphnia sp.)**
    Prawn (M. rosenbergii) - Corbin et al. (1983)
    Crayfish (A. astacus/P. Leniusculus/P. clarkii) - Brown et al. (1992), Celada et al. (1993), Hessen (1989)

Table 4. contd.

MOLLUSCS

1. **Short-necked clam (Venerupis philippinarum)**
   Shrimp (P. japonicus, P. vannamei) - Deshimaru & Shigeno (1972), Deshimaru (1981), Mito & Fukuhara (1988), Ogle & Beaugez (1991), Teshima et al. (1988)

2. **Black clam (Villorita cyprinoides), Marine clam (Sunetta scripta)**
   Shrimp (general) - Kripa & Joseph (1992)

3. **Clam (Mercenaria mercinaria)**
   Shrimp (P. vannamei/P. stylirostris) - Chamberlain & Lawrence (1981)

4. **Clam (Meretrix casta)**
   Spiny lobster (P. homarus) - Vijayakumaran & Radhakrishnan (1984)
   Mud crab (S. serrata) - How-Cheong, Gunasekera & Amandakoon (1992)

5. **Clam (Protothaca taca, Argopecten purpuratus)**
   Shrimp (P. vannamei) - Meruane & Rivera (1992)

6. **Clam (general)**
   Shrimp (general) - Lim & Persyn (1989), Muthu (1983), Shang (1989), Yano (1984)

7. **Blue mussel (Mytilus edulis)**
   Shrimp (P. japonicus/P. monodon/P. setiferus/Palaemon serratus/P. kerathurus/P. merguiensis/P. orientalis) - Arnstein & Beard (1975), Beard & Wickins (1980), Beard et al. (1977), Brown et al. (1979), Chiang & Liao (1985), Chuang (1990), Cruz et al. (1990), Cuzon et al. 1981; Deshimaru & Shigeno (1972), Fernandez & Puchal (1979), Forster & Beard (1973), Lim & Persyn (1989), Mito & Fukuhara (1988), Solis (1988)
   Prawn (M. rosenbergii) - Wickins & Beard (1974)

8. **Green mussel (Perna/Mytilus viridis)**
   Shrimp (P. vannamei/P. stylirostris/P. indicus) - Galgani et al. (1989a, 1989b), Makinouchi & Primavera (1987)
   Prawn (M. rosenbergii) - Liao & Chao (1982)

9. **Mussel (general)**
   Shrimp (general) - Muthu (1983)
   Lobster (H. americanus) - Conklin & Chang (1983)
   Crayfish (P. leniusculus) - Celada et al. (1989)

10. **Horse mussel (Modiolus sp.)**
    Mud crab (S. serrata) - Prinpanapong & Youngwanichsaed (1992)

11. **Oyster (Crassostera virginica)**
    Shrimp (P. vannamei) - Ogle & Beaugez (1991)

12. **Oyster (general)**
    Shrimp (P. monodon/P. merguiensis/P. setiferus/P. schmitti) - Brown, McVey et al. (1979), Lawrence et al. (1980), Liong et al. (1988), Muthu (1983), Nascimento et al. (1991)

13. **Conch (Strombus gigas)**
    Shrimp (P. vannamei) - Ogle & Beaugez (1991)

Table 4. contd.

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14. Golden snail (Ampullaria sp.)
    Shrimp (P. monodon) - Solis (1988)

15. Topshell (Trocus niloticus)
    Shrimp (P. vannamei/P. stylirostris/P. indicus) - Galgani et al. (1989a, 1989b)

16. Snails (general)
    Shrimp (P. monodon/P. vannamei) - Chamberlain (1991), Corre (1988), Mervane & Rivera (1992)
    Prawn (M. rosenbergii) - Corbin et al. (1983)

17. Squid (Lolliguncula brevis)
    Shrimp (P. vannamei) - Ogle & Beaugez (1991)

18. Squid (Notodarius sloani)
    Shrimp (P. vannamei/P. stylirostris/P. indicus) - Galgani et al. (1989a, 1989b)

19. Squid (Loligo sp. & Lolloguncula sp.)
    Shrimp (P.vannamei/P.stylirostris/P.schmitti/P.setiferus,P.monodon)- Brown et al. (1979), Chamberlain & Lawrence (1981), Lawrence et al. (1980), Nascimento et al. (1991), Millamena et al. (1986)

20. Squid (Sepioteuthis sp.)
    Prawn (M. australiense) - Lee & Fielder (1982)

21. Squid (general)
    Shrimp (general) - Lim & Persyn (1989), Makinouchi & Primavera (1987), Muthu (1983)

ANNELIDS

1. Maine bloodworm (Glycera dibranchiata)
    Shrimp (P. vannamei/P. stylirostris/P. schmitti/P. setiferus) - Brown et al. (1979), Chamberlain & Lawrence (1981), Nascimento et al. (1991), Ogle & Beaugez (1991), Yano et al. (1988)

2. Panama bloodworm (Americonuphis reesei)
    Shrimp (P. vannamei) - Ogle & Beaugez (1991)

3. Sandworm (Nereis virens)
    Shrimp (P. vannamei/P. setiferus) - Brown et al. (1979), Lawrence et al. (1980), Ogle & Beaugez (1991)

4. Marine annelids (general)
    Shrimp (P. monodon/P. indicus)-Makinouchi & Primavera (1987), Millamena et al. (1986)

5. Earthworm (Lumbricus terrestris/Eisenia foetida)
    Crayfish (P. clarkii/P. acutus/A. astacus) - Hessen (1989), Sanguanruang & Romaire (1988), Merrick & Lambert (1991)
    Prawn (M. rosenbergii) - Mossmann et al. (1990)

6. Earthworm (general)
    Shrimp (P. monodon) - Solis (1988)

Table 4. contd.

ECHINODERMS

1. Sea urchin (Strongylocentrotus droebachiensis)
   Lobster (H. americanus) - Evans & Mann (1977)

INSECTS

1. Aquatic insect larvae (general)
   Crayfish (general) - Hessen (1989), Merrick & Lambert (1991)

FISH

1. Anchovy (Anchoa mitchilli, Stolephorus sp.)
   Shrimp (P. vannamei/P. monodon) - Djunaidah et al. (1990), Ogle & Beaugez (1991)

2. Skipjack tuna (Kluyveromyces fragilis)
   Shrimp (P. vannamei/P. stylirostris) - Galgani et al. (1989)

3. Tilapia (Tilapia mossambica)
   Shrimp (P. monodon) - Apud et al. (1981)

4. Rainbow trout (Oncorhynchus mykiss)
   Crayfish (P. leniusculus) - Celada et al. (1989), (1993)

5. Trash fish (general)
   Shrimp (P. monodon, P. japonicus) - Chamberlain (1991), Chiang & Liao (1985), Deshimaru & Shigeno (1972), Lim & Persyn (1989), Solis (1988)
   Prawn (M. rosenbergii) - Liao & Chao (1982), Corbin et al. (1983), Lee & Fielder (1982)
   Lobster (H. americanus) - Syslo & Hughes (1981)
   Crayfish (A. astacus) - Hessen (1989)
   Mud crab (S. serrata) - Angell (1992), How-Cheong, Gunasekera & Amandakoon (1992)
   Lobster (P. argus) - Quackenbush & Herrnkind (1981)

6. Fish eggs (general)
   Crayfish (A. astacus) - Hessen (1989)
   Prawn (M. rosenbergii) - Corbin et al. (1983)

AMPHIBIANS

1. Frogs (Rana sp.)
   Shrimp (general) - Corre (1988)

VERTEBRATES

1. Liver (Pork)
   Lobster (H. americanus) - Conklin et al. (1978)
   Crayfish (P. leniusculus) - Celada et al. (1989)

   Liver (Beef)
   Prawn (M. rosenbergii) - Garces & Heinen (1993)

2. Slaughterhouse waste (general)
   Mud crab (S. serrata) - Angell (1992), How-Cheong, Gunasekera & Amandakoon (1992)

Table 4. contd.

PLANTS

1. Seaweeds (eelgrass Zostera marina, Japanese weed Codium fragile, Irish moss Chondrus crispus, rockweed Fucus spiralis, kelp Laminaria sp.
Lobster (H. americanus) - Syslo & Hughes (1981) 2/

2. Aquatic macrophytes (water velvet Azolla filiculoides, filamentous green algae Cladophera sp., waterweed Elodea sp., duckweed Lemna sp.
Prawn (M.rosenbergii)-Stern et al., (1976)2/

3. Aquatic macrophytes (alligator weed Alternanthera philoxeroides, water primrose ludwigia sp., smart weed polygonum sp., myriophyllum spicatus, filamentous green algae Spirogyra sp.
Crayfish (P. clarkii/P. acutus) - Avault & Brunson (1990), Brown et al. (1992), Sanguanruang & Romaire (1988) 2/

4. Aquatic macrophytes (water weed Elodea sp., Egeria densa)
Crayfish (P. clarkii) - Huner (1984)

5. Aquatic macrophytes (sea grass Halophila ovalis, filamentous algae Chaetomorpha sp. & Enteromorpha sp.)
Mud crab (S.serrata) - Raman et al. (1980)

6. Aquatic macrophyte (Duckweed Lemna sp.)
Prawn (M. rosenbergii) - Corbin et al. (1983)

7. Aquatic macrophyte (Ruppia maritima)
Shrimp (P. monodon) - Bombeo-Tuburan, Guanzon & Schroeder (1993), Primavera & Gacutan (1989)

8. Aquatic macro alga (Enteromorpha sp.)
Shrimp (P. stylirostris/P. monodon) - Bray & Lawrence (1992), Bray et al. (1990)

9. Aquatic macrophyte (Zygogonium ericetorium, Nasturtium officinale)
Crayfish (P. leniusculus) - Celada et al. (1989), (1993)

10. Rice (Oryza sativa)
Crayfish (P. clarkii/P. acutus) - Avault & Brunson (1990), Sanguanruang & Romaire (1988)

11. Tree leaves (Ailanthus altissima, Malva parviflora)
Prawn (M. rosenbergii) - Harpaz & Schmalbach, (1986) 3/

12. Bean sprouts (general)
Prawn (M. rosenbergii) - Corbin et al. (1983)

13. Sweet potato (Ipomoea batatas) trimmings and vines
Crayfish (P. clarkii/P. acutus) - Avault & Brunson (1990)

14. Miscellaneous fresh and frozen fruits and vegetables
Prawn (M. rosenbergii) - Garces & Heinen (1993)

1/ Gonad and digestive tissue
2/ Animals lost weight when fed a diet composed of 100% seaweed or aquatic macrophyte
3/ Fresh leaves

Table 5. Major processed feed ingredients used within practical feeds for cultured decapod postlarvae

Ingredient name/Culture system:Diet level used 1/

INVERTEBRATE ANIMAL BY-PRODUCTS

Squid meal

Shrimp (P.aztecus/P.indicus/P.kerathurus/P.japonicus/P.merguiensis/P.monodon/P.setiferus/P.stylirostris/P.vannamei)
- Tank:2-71% :- Akiyama (1988); Cruz-Suarez, Ricque & Aquacop (1992); De la Cruz, et al. (1989); Deshimaru & Shigeno (1972); Eusebio (1991); Fenucci & Zein-Eldin (1976); Dominy & Ako (1988); Fenucci, etal. (1980); Fernandez & Puchal (1979); Galgani et al. (1989); Kanazawa (1989); Koshio, Kanazawa & Teshima (1992); Lim & Dominy (1990); Manik et al. (1980); Meyers (1988); Millamena et al. (1986); Shiau & Chou (1991); Sumeru (1989); Teshima et al. (1991)

Shrimp (P. monodon/P. stylirostris/P. vannamei)
- Cage/Pond:General:2-10% :- Akiyama (1988), (1993); Bostock (1990); Chuang (1990); Cruz-Suarez, Ricque & Aquacop (1992), Dominy, Huber & Castaldo (1991); Garcia-Casas (1990); Kongkeo (1990); Lim & Persyn (1989); Unprasert (1989)

Prawn (M. rosenbergii)
- Tank:20% (squid mantle) :- Heinen & Mensi (1991)

Crayfish (C. tenuimanus)
- Tank:2.5% (Loligo sp.) :- Villarreal (1991)

Squid offal/viscera

Shrimp (P. indicus/P. monodon)
- Cage/Pond:50-100% (boiled) :- Angell (1988); Natarajan et al. (1987)

Shrimp (P. vannamei)
- Tank:40-60% (co-extruded with soybean meal or wet shrimp heads) :- Carver et al. (1988); Dominy & Lim (1991)

Shrimp meal/shrimp head meal (non-specific)

Shrimp (P.aztecus/P.californiensis/P.indicus/P.kerathurus/P.japonicus/P.merguiensis/P.monodon/P.setiferus/P.stylirostris/P.vannamei/M.monoceros)
- Tank:2-86% :- Ahamad Ali (1992); Akiyama (1988); Anggawati (1992); Balazs et al. (1973); Brand & Colvin (1977); Chen et al. (1985); Cruz-Ricque et al. (1987); Cruz-Suarez et al. (1987), Cruz-Suarez et al. (1991), (1993); Cruz-Suarez, Ricque & Aquacop (1992); Cuzon et al. (1981); De la Cruz et al. (1989); Deshimaru & Shigeno (1972); Deshimaru et al. (1985); Dominy & Ako (1988); Eusebio (1991); Faranda et al. (1984); Fenucci & Zein-Eldin (1976); Fenucci et al. (1980); Fernandez & Puchal (1979); Galgani & Ceccaldi (1988); Galgani et al. (1989); Godfred et al. (1991); Lawrence et al. (1986); Lim & Dominy (1990), (1992); Millamena et al. (1986); Murai, Sumalangcay & Piedad-Pascual (1985); Pascual & Destajo (1978); Penaflorida, Pascual & Tabbu (1992); Rajyalakshmi et al. (1986); Shiau & Chou (1991); Ung & Junilla (1989); Villarreal et al. (1991); Zein-Eldin & Corliss (1976)

Table 5. contd.

Shrimp (P. japonicus/P. monodon/P.vannamei)
- Cage/Pond:General:3-30% :- Akiyama (1988), (1993); Akiyama et al. (1991); Aquacop(1977); Angell (1988); Bostock (1991); Cam et al. (1991); Chuang (1990); Cruz-Suarez, Ricque & Aquacop (1992); Dominy et al. (1991); Hassan et al. (1984); Kongkeo (1990); Lim & Persyn (1989); Meyers (1988); Pascual (1989); Sriraman & Narayanan (1987) Sumeru (1989); Unprasert (1989); Wood & Coulter (1988)

Prawn (M. rosenbergii)
- Tank:12-44% :- Balazs & Ross (1976); Law et al. (1990); Manik (1976); Ravishankar & Keshavanath (1988); Thong (1985)

- Pond:General:4-45% :- Boonyaratpalin & New (1982); Boonyaratpalin & Vorasayan (1983); Maclean et al. (1989); Manik (1980); New & Singholka (1982)

Lobster (H. americanus)
- Tank:1-25% :- Conklin et al. (1983); D'Abramo et al. (1981)

Crayfish (P. clarkii/C. destructor)
- Tank:5-31% :- D'Abramo et al. (1985); Huner et al. (1975); Lochmann, McClain & Gatlin (1992); Merrick & Lambert (1991)

Crab (S. serrata)
- Tank:15-60% :- How-Cheong, Gunasekera & Amandokoon (1992); Srinivasagam & Kathirvel (1992)

Crayfish (Cherax tenuimanus) meal

Crayfish (C. cuspidatus)
- Tank:5% :- Villarreal (1991)

Shrimp (Acetes sp.) meal

Shrimp (P. monodon)
- Tank:15-100% :- Catacutan (1991); Kungvankij et al. (1986); Tacon (1986); Vogt et al. (1986)

- Cages:10-20/m^2:15% :- Pascual et al. (1990)

Prawn (M. rosenbergii)
- Tank:20% :- Manik (1976)

Mantis shrimp (Oratosquilla nepa) meal

Shrimp (P. indicus)
- Tank:68% :- Ahamad Ali (1992)

Table 5. contd.

Krill meal

Shrimp (P. japonicus/P. monodon)
- Tank:5-53% :- Kanazawa (1989); Koshio, Kanazawa & Teshima (1992); Murai, Sumalangcay & Piedad-Pascual (1983); Teshima et al. (1991); Palmegiano, Forneris & Sarra (1986)

Crab meal

Shrimp (P. californiensis)
- Tank:10% (red crab Pleuroncodes planipes) :- Villarreal et al. (1991)

Shrimp (P. vannamei/P. stylirostris)
- Pond:10/m^2:10% :- Garcia-Casas (1990)

Crab protein concentrate

Shrimp (P. japonicus)
- Tank:17-44% :- Koshio, Kanazawa & Teshima (1992)

Prawn (M. rosenbergii)
- Tank:30-60% :- Koshio, Kanazawa & Teshima (1992)

Lobster (H. americanus)
- Tank:36% :- Koshio, Castell & O'Dor (1992)

Mussel (Mytilus sp.) meal

Shrimp (P. merguiensis)
- Tank:79% :- Sedgwick (1980)

Shrimp (P. indicus)
- Tank:28.6% (wet,w/w) :- Galgani et al. (1989)

Shrimp (general)
- Pond/Tank:5% :- Kongkeo (1990)

Short-necked clam (V. phillippinarum) extract

Shrimp (P. japonicus)
- Tank:4% :- Kanazawa (1989)

Clam (Sunneta scripta) meat powder

Shrimp (P. indicus)
- Tank:51% :- Ahamad Ali (1992)

Clam (meat) meal

Shrimp (general)
- Pond:General :- Meyers (1988); Wood & Coulter (1988)

Table 5. contd.

Prawn (M. rosenbergii)
- Tank:20-100% :- Mohanakumaran Nair & Sherief (1992)

Snail (Trocus sp.) meal

Prawn (M. rosenbergii)
- Tank:15% :- Aquacop (1976)

Housefly (Musca domestica) pupae meal

Shrimp (P. californiensis)
- Tank:28% :- Tinsley et al. (1984)

Silkworm (Bombyx mori) pupae meal

Shrimp (P. indicus)
- Tank:50% :- Ahamad Ali (1992)

Prawn (M. rosenbergii)
- Tank:23-60% :- Ravishankar & Keshavanath (1988)

Earthworm (sp. not specified) meal

Shrimp (P. indicus)
- Tank:5% :- Murai, Sumalangcay & Piedad-Pascual (1983); Pascual (1985)

VERTEBRATE ANIMAL BY-PRODUCTS

Fish meal (non-defined)

Shrimp (P.californiensis/P.indicus/P.kerathurus/P.japonicus/P.merguiensis/P.monodon/P.setiferus/P.stylirostris/P.vannamei)
- Tank:5-50% :- Ahamad Ali (1992); Akiyama (1988); Anggawati (1992); Cruz-Suarez et al. (1987), (1993); Cuzon et al. (1981); De la Cruz et al. (1989); Deshimaru et al. (1985); Dominy & Ako (1988); Eusebio (1991); Fenucci et al. (1980); Fernandez & Puchal (1979); Galgani & Ceccaldi (1988); Galgani et al. (1989); Kanazawa (1989); Koshio, Kanazawa & Teshima (1992); Lin et al. (1981); Millamena et al. (1986); Murai, Sumalangcay & Piedad-Pascual (1983); Palmegiano, Forneris & Sarra (1986); Pascual & Catacutan (1990); Pascual & Destajo (1978); Penaflorida, Pascual & Tabbu (1992); Rayyalakshmi et al. (1986); Teshima et al. (1991); Villarreal et al. (1991); Vogt et al. (1986)

Shrimp (P. monodon/P. stylirostris/P. vannamei)
- Pond-3-40% :- Akiyama (1988), (1993); Bostock (1991); Chuang (1990); Dominy et al. (1991); Garcia-Casas (1990); Hassan et al. (1984); Kongkeo (1990); Lim & Persyn (1989); Meyers (1988); Pascual (1989); Sumeru (1989); Unprasert (1989)

Prawn (M. rosenbergii)
- Tank/Pond:General:4-60% :- Aquacop (1976); Boonyaratpalin & New (1982); Boonyaratpalin & Vorasayan (1983); Haroon (1990); Law et al. (1990); Maclean et al. (1989); Manik (1976, 1980); Ravishankar & Keshavanath (1988); Tidwell et al. (1993)

Table 5. contd.

Crayfish (P. clarkii/C. destructor/C. tenuimanus)
- Tank:2-60% :- D'Abramo et al. (1985); Huner et al. (1975); Merrick & Lambert (1991)

Crab (S. serrata)
- Tank:5% :- How-Cheong, Gunasekera & Amandakoon (1992)

Menhaden (Brevoortia tyrannus) fish meal

Shrimp (P. aztecus/P. californiensis)
- Tank:3-30% :- Akiyama (1988); Brand & Colvin (1977); Fennucci & Zein-Eldin (1976); Zein-Eldin & Corliss (1976)

Prawn (M. rosenbergii)
- Tank:20-45% :- Clifford & Brick (1979)

Crayfish (P. clarkii)
- Tank:5% :- Lochmann, McClain & Gatlin (1992)

Tuna (Thumus sp.) fish meal

Shrimp (P. monodon/P. vannamei)
- Tank:3-35% :- Cruz-Suarez, Robledo de Leon & Ricque (1992); Trino et al. (1992)

Prawn (M. rosenbergii)
- Tank/Pond:General:5-12% :- Balazs & Ross (1976); Corbin et al. (1983)

Lobster (H. americanus)
- Tank:4-19% :- D'Abramo et al. (1985); Goddard (1988)

Anchovy (Engraulis ringens) fish meal

Shrimp (P. vannamei)
- Tank:6-28% :- Lim & Dominy (1990), (1992)

Peruvian fish meal

Shrimp (P. monodon)
- Tank:9% :- Catacutan (1991)
- Pond:10-20/m^2:9-30% :- Pascual et al. (1990)

Norwegian fish meal

Shrimp (P. japonicus)
- Pond:2-20/m^2:10% :- Cam et al. (1991)

Hawaiian fish meal

Shrimp (P. aztecus/P. japonicus)
- Tank:7-20% :- Balazs et al. (1973)

Prawn (M. rosenbergii)
- Tank:7-29% :- Balazs et al. (1973)

Table 5. contd.

Thai fish meal
Shrimp (P. monodon)
- Tank:30% :- Ung & Junilla (1989)

Dried fish solubles

Shrimp (P.aztecus/P.californiensis/P.monodon/P.setiferus/P.vannamei)
- Tank/Pond:General:2-5% :- Akiyama (1988); Brand & Colvin (1977); Chen et al. (1985); Chuang (1990); Cuzon et al. (1982); Dominy et al. (1991); Fenucci et al. (1980); Sumeru (1989); Zein-Eldin & Corliss (1976)

Fish protein concentrate/hydrolysate

Shrimp (P.indicus/P.japonicus/P.monodon/P.setiferus/P.stylirostris/P.vannamei
- Tank:2-26% :- Aquacop & Cuzon (1989); Anggawati (1992); Chen et al. (1985); Cruz-Ricque et al. (1987); Cruz-Suarez, Ricque & Aquacop (1992); Cuzon et al. (1981); Galgani & Ceccaldi (1988); Galgani et al. (1989)

Shrimp (P.japonicus/P.monodon)
- Pond:2-20/m^2:5-18% :- Aquacop (1977); Cam et al. (1991); Cruz-Suarez, Ricque & Aquacop (1992)

Crayfish (General)
- Tank:2% :- Huner et al. (1975)

Fish (Macroramphosus scolopax) silage

Shrimp (Palaemon serratus)
- Tank:40% (protein inclusion level) :- Luis & Batista (1990)

Trash fish

Shrimp (General)
- Pond:General:10-60% :- Angell (1988); Bostock (1991); Unprasert (1989)

Prawn (M. rosenbergii)
- Pond:General:52-72% :- Boonyaratpalin & Vorasayan (1983)

Crab (S. serrata)
- Tank:30% :- How-Cheong, Gunasekera & Amandakoon (1992)

Liver (beef) meal

Shrimp (Leptocarpus sp.)
- Tank:21% :- Goswami & Goswami (1979)

Prawn (M. rosenbergii)
- Tank:20% :- Heinen & Mensi (1991)

Poultry by-product meal

Shrimp (P. vannamei/P. stylirostris)
- Pond:10/m^2:11-15% :- Garcia-Casas (1990)

Table 5. contd.

Meat and Bone meal

Shrimp (P. vannamei)
- Tank:10-40% :- Lawrence & Castille (1988)

Prawn (M. rosenbergii)
- Pond/Tank:7-11% :- Corbin et al. (1983)
  Pond:2/M^2:8% :- Tidwell et al. (1993)

Meat meal

Shrimp (P. japonicus)
- Tank:5% :- Cuzon et al. (1981)

Shrimp (P. monodon)
- Pond:10/m^2:21% :- Aquacop (1977)

Crayfish (C. destructor)
- Tank:50% :- Merrick & Lambert (1991)

Crab (S. serrata)
- Tank:2% :- How-Cheong, Gunasekera & Amandakoon (1992)

Blood meal

Shrimp (P. californiensis/P. indicus/P. monodon/P. vannamei/P. paulensis/P. japonicus)
- Tank:2-35% :- Brand & Colvin (1977); Cruz-Ricque et al.et al. (1987); Dominy & Ako (1988); Galgani & Ceccaldi (1988); Palmegiano, Forneris & Sarra (1986); Marchiori et al. (1982)

Shrimp (P. monodon)
- Pond:10/m^2:9-11% :- Aquacop (1977)

Prawn (M. rosenbergii)
- Tank:5% :- Aquacop (1976)

Feather meal

Shrimp (P. japonicus)
- Tank:15-23% :- Teshima et al. (1991)

Buffalo meat (cooked)

Shrimp (general)
- Pond:General:40% :- Wood & Coulter (1988); Wood & Brown (1990)

Table 5. contd.

OILSEEDS AND GRAIN LEGUMES

Soybean (Glycine max) meal

Shrimp (P.californiensis/P.indicus/P.japonicus/P.merguiensis/P.monodon/P.setiferus/P.stylirostris/P.vannamei/L.potamiscus)
- Tank:8-70% :- Akiyama (1988); Anggawati (1992); Brand & Colvin (1977); Chen et al. (1985); Cruz-Suarez, Ricque & Aquacop (1992); Cruz-Suarez et al. (1993); Cuzon et al. (1982); De la Cruz et al. (1989); Deshimaru et al. (1985); Eusebio (1991); Fenucci & Zein-Eldin (1976); Fernandez & Lawrence (1988); Galgani & Ceccaldi (1988); Goswami & Goswami (1979); Kanazawa (1989); Lim & Dominy (1990), (1992); Palmegiano, Forneris & Sarra (1986); Pascual & Catacutan (1990); Rajyalakshmi et al. (1986); Trino et al. (1992); Ung & Junilla (1989); Villarreal et al. (1991)

Shrimp (P. monodon/P. vannamei)
- Tank:9-36% (full-fat) :- Catacutan (1991); Lim & Dominy (1992); Murai, Sumalangcay & Piedad-Pascual (1983)

Shrimp (P. monodon)
- Tank:4-20% (protein concentrate) :- Aquacop & Cuzon (1989); Galgani & Ceccaldi (1988); Galgani et al. (1989)

Shrimp (P.indicus/P.japonicus/P.monodon/P.stylirostris/P.vannamei)
- Cage/Pond:General/2-20/m^2:5-55% :- Akiyama (1988), (1993); Aquacop (1976); Aquacop & Cuzon (1989); Bostock (1991); Cam et al. (1991); Chuang (1990); Cruz-Suarez, Ricque & Aquacop (1992); Dominy et al. (1991); Garcia-Casas (1990); Hassan et al. (1984); Kongkeo (1990); Lim & Persyn (1989); Pascual (1989); Pascual et al. (1990); Sumeru (1989); Unprasert (1989); Wood & Coulter (1988)

Prawn (M. rosenbergii)
- Tank:2-68% :- Balazs & Ross (1976); Balazs et al. (1973); Boonyaratpalin & New (1982); Clifford & Brick (1979)

- Tank:27-53% (protein concentrate) :- Koshio et al. (1992)

- Pond:General:5-43% :- Boonyaratpalin & Vorasayan (1983); Corbin et al. (1983); Maclean et al. (1989); Manik (1976; 1980); Tidwell et al. (1993)

Crayfish (C. destructor/P. clarkii/C. tenuimanus)
- Tank:5-68% :- Lochmann, McClain & Gatlin (1992); Merrick & Lambert (1991); Villarreal (1991)

Crayfish (P. clarkii)
- Tank:18% (full-fat) :- D'Abramo et al. (1985)

Crayfish (General)
- Tank:3% (protein concentrate) :- Huner et al. (1975)

Lobster (H. americanus)
- Tank:3% :- Capuzzo & Lancaster (1979)

Table 5. contd.

Crab (S. serrata)
- Tank:40% :- How-Cheong, Gunasekera & Amandakoon (1992)

Soy lecithin

Shrimp (P.aztecus/P.indicus/P.kerathurus/P.monodon/P.setiferus/P.stylirostris/P.vannamei)
- Tank:0.5-3% :- Akiyama (1988); Aquacop & Cuzon (1989); Catacutan (1991); Chen et al. (1985); Cuzon & Aquacop (1989); Cruz-Suarez et al. (1987), (1992), (1993); De la Cruz et al. (1989); Deshimaru et al. (1985); Fenucci & Zein-Eldin (1976); Fernandez & Puchal (1979); Galgani & Ceccaldi (1988); Galgani et al. (1989); Kanazawa (1989); Lim & Dominy (1990); Pascual (1989); Trino et al. (1992); Zein-Eldin & Corliss (1976)

- Pond:General:0.5-2% :- Akiyama (1988), (1993); Bostock (1991); Garcia-Casas (1990); Lim & Persyn (1989)

Prawn (M. rosenbergii)
- Tank:2% :- Koshio et al. (1992); Pascual (1989);

Crayfish (P. clarkii)
- Tank:1-8% :- D'Abramo et al. (1985); Huner et al. (1975); Lochmann, McClain & Gatlin (1992)

Soybean (G. max) stubble and hay

Crayfish (general)
- Pond:General :- Avault & Brunson (1990)

Cottonseed (Gossypium sp.) meal

Shrimp (P. setiferus/P. stylirostris/P. vannamei)
- Tank:4-20% :- Chen et al. (1985); Dominy et al. (1991); Fernandez & Lawrence (1988)

Prawn (M. rosenbergii)
- Tank/Pond:General:10-16% :- Corbin et al. (1983)

Peanut (Arachis hypogaea) meal

Shrimp (P. monodon/P. indicus/P. semisulcatus/M. monoceros)
- Tank:18-62% (oilcake) :- Ahamad Ali (1992); Godfred et al. (1991); Rajyalakshmi et al. (1986)

Shrimp (P. monodon/P. indicus)
- Cage/Pond:General:10-20% (oilcake) :- Aquacop (1977); Natarajan et al. (1987); Wood & Coulter (1988)

Prawn (M. rosenbergii)
- Tank/Pond:General:2-26% :- Aquacop (1976); Boonyaratpalin & New (1982); Ravishankar & Keshavanath (1988)

Crayfish (P. clarkii)
- Tank:25-48% :- Lochmann, McClain & Gatlin (1992)

Table 5. contd.

Crab (S. serrata)
- Tank:Pond:General:36% :- Srinivasagam & Kathirvel (1992)

Cowpea (Vigna unguiculata) meal

Shrimp (P. monodon)
- Tank:25-30% (whole & dehulled) :- Eusebio (1991)

Rice bean (Phaseolus calcaratus) meal

Shrimp (P. monodon)
- Tank:24% (whole & dehulled) :- Eusebio (1991)

Coconut (Cocus nucifera) meal

Shrimp (P. indicus)
- Tank:72% :- Ahamad Ali (1992)

Prawn (M. rosenbergii)
- Tank/Pond:10-30/m^2:1-44% :- Aquacop (1976); Maclean et al. (1989); Thong (1985)

- Tank/Pond:General:14-21% (oilcake) :- Law et al. (1990); Manik (1976, 1980)

Mustard (Brassica sp.) meal

Prawn (M. rosenbergii)
- Pond:1-2/m^2:30% :- Haroon (1990)

CEREAL GRAINS AND BY-PRODUCTS

Rice (Oryza sativa) bran

Shrimp (P.aztecus/P.indicus/P.merguiensis/P.monodon/P.semisulcatus/P.setiferus /P.vannamei/M.monoceros)
- Tank:5-52% :- Akiyama (1988): Chen et al. (1985); De la Cruz et al. (1989); Eusebio (1991); Fenucci et al. (1980); Godfred et al. (1991); Hassan et al. (1984); Millamena et al. (1986); Pascual (1989); Pascual & Catacutan (1990); Rajyalakshmi et al. (1986); Trino et al. (1992)

Shrimp (P. monodon:General)
- Cage/Pond:General:5-60% :- Akiyama (1988); Bostock (1991); Pascual et al. (1990); Sumeru (1989); Wood & Coulter (1988)

Prawn (M. rosenbergii)
- Tank:15-20% :- Manik (1976)

- Tank/Pond:3-39% :- Boonyaratpalin & New 91982); Boonyaratpalin & Vorasayan (1983); Haroon (1990)

Crayfish (P. clarkii)
- Tank:6-34% :- D'Abramo et al. (1985); Huner et al. (1975)

Table 5. contd.

Crab (S. serrata)
- Tank/Pond:General:36% :- Srinivasagam & Kathirvel (1992)

Rice (Oryza sativa) hulls

Shrimp (P. monodon)
- Pond:0.3/m^2:100% :- Subosa (1992)

Rice (O. sativa) polished

Prawn (M. rosenbergii)
- Tank/Pond:30/m^2:15% :- Aquacop (1976)

Crab (S. serrata)
- Tank:20% :- How-Cheong, Gunasekera & Amandakoon (1992)

Rice (O. sativa) broken

Shrimp (General)
- Tank/Pond:General:5-15% :- Bostock (1991); Kongkeo (1990); Unprasert (1989)

Prawn (M. rosenbergii)
- Tank/Pond:General:5-39% :- Boonyaratpalin & New (1982); Boonyaratpalin & Vorasayan (1983)

Rice (O. sativa) flour

Shrimp (P. monodon)
- Tank:7-30% (extruded) :- Sheen & Chen (1991)

Rice (O. sativa) straw

Prawn (M. rosenbergii)
- Pond:3/m^2:9.8g/m^2/week :- Miltner et al. (1983)

Crayfish (P. acutus)
- Tank:100% (microbially modified) :- Lewis et al. (1988)

Crayfish (P. acutus/P. clarkii)
- Pond:general :- Avault & Brunson (1990)

Rye (Secale cereale) hay

Crayfish (General)
- Pond:General :- Avault & Brunson (1990)

Wheat (Triticum sp.) flour

Shrimp (L. potamiscus/P. aztecus/P. japonicus/P. monodon//P. vannamei)
- Tank:1-39% :- Akiyama (1988); Anggawati (1992); Balazs, Ross & Brooks (1973); De la Cruz et al. (1989); Cruz-Suarez et al. (1993); Deshimaru et al. (1985); Dominy & Ako (1988); Eusebio (1991); Goswami & Goswami (1979); Lim & Dominy (1990), (1992); Millamena et al. (1986); Pascual (1989); Pascual & Destajo (1978); Penaflorida, Pascual & Tabbu (1992); Rajyalakshmi et al. (1986); Sheen & Chen (1991); Shiau et al. (1991); Trino et al. (1992); Ung & Junilla (1989); Vogt et al. (1986)

Table 5 contd.

Shrimp (P. monodon/general)
- Cage/Pond:General:1-44% :- Akiyama (1988), (1993); Bostock (1991); Chuang (1990); Dominy et al. (1991); Kongkeo (1990); Meyers (1988); Pascual et al. (1990); Sumeru (1989)

Prawn (M. rosenbergii)
- Tank:10-50% (high gluten) :- Balazs & Ross (1976); Law et al. (1990); Manik (1976); Thong (1985)

- Pond:2-10/m^2:13-33% :- Maclean et al. (1989); Tidwell et al. (1993)

Crayfish (P. clarkii/C. destructor)
- Tank:5-20% :- D'Abramo et al. (1985); Merrick & Lambert (1991)

Crab (S. serrata)
- Tank:10-40% :- How-Cheong, Gunasekera & Amandakoon (1992), Srinivasagam & Kathirvel (1992)

Wheat (Triticum sp.) whole meal

Shrimp (P. indicus/P. monodon/P. stylirostris/P. vannamei)
- Tank:13-21% :- Cruz-Ricque et al. (1987); Cruz-Suarez, Ricque & Aquacop (1992); Galgani et al. (1989)

Prawn (M. rosenbergii)
- Tank/Pond:30/m^2:5-36% :- Aquacop (1976); Ashmore et al. (1986)

Crayfish (C. tenuimanus)
- Tank:2-60% :- Villarreal (1991)

Wheat (Triticum sp.) middlings/pollard

Shrimp (P. monodon/General)
- Tank/Cage/Pond:4-23% :- Akiyama (1988), (1993); Dominy et al. (1991); Ung & Junilla (1989)

Crayfish (C. destructor)
- Tank:20% :- Merrick & Lambert (1991)

Wheat (Triticum sp.) bran

Shrimp (P. monodon/General)
- Tank/Pond:General:4-12% :- Akiyama (1988); Meyers (1988)

Prawn (M. rosenbergii)
- Pond:1-2/m^2:20% :- Haroon (1990)

Crayfish (C. destructor/P. leniusculus)
- Tank:10-17% :- Celada et al. (1993); Merrick & Lambert (1991)

Crab (S. serrata)
- Tank:7% :- How-Cheong, Gunasekera & Amandakoon (1992)

Table 5 contd.

Wheat (Triticum sp.) gluten

Shrimp (P. indicus/P. japonicus/P. merguiensis/P. monodon/P. stylirostris/P. vannamei)
- Tank:2-24% :- Akiyama (1988); Cruz-Ricque et al. (1987); Cruz-Suarez et al. (1987); Cruz-Suarez, Ricque & Aquacop (1992); Cuzon et al. (1982); Deshimaru & Shigeno (1972); Deshimaru et al. (1985); Galgani & Ceccaldi (1988); Galgani et al. (1989); Teshima et al. (1991); Trino et al. (1992)

- Pond:General:2-12% :- Cam et al. (1991); Chuang (1990); Garcia-Casas (1990); Dominy et al. (1991)

Lobster (H. americanus)
- Tank:4-15% :- Conklin et al. (1983); Koshio, Castell & O'Dor (1992)

Crayfish (P. clarkii)
- Tank:8% :- D'Abramo et al. (1985)

Wheat (Triticum) sp.) straw

Crayfish (P. acutus)
- Tank:100% (microbially modified) :- Lewis et al. (1988)

Corn/Maize (Zea mays) whole meal

Shrimp (P. aztecus/P. japonicus/P. monodon)
- Tank/Pond:General:9-40% :- Balazs et al. (1973); Hassan et al. (1984)

Prawn (M. rosenbergii)
- Tank/Pond:General:3-57% :- Ashmore et al. (1986); Balazs et al. (1973); Corbin et al. (1983); Manik (1976); Tidwell et al. (1993)

Crayfish (C. destructor/C. lenuimanus)
- Tank:10-26% :- Merrick & Lambert (1991); Villarreal (1991)

Corn/Maize (Zea mays) flour

Shrimp (P. monodon)
- Tank:36% :- Rajyalakshmi et al. (1986)

Corn/Maize (Zea mays) gluten

Shrimp (P. monodon/P. vannamei)
- Tank:5-10% :- Cruz-Suarez et al. (1993); Ung & Junilla (1989)

Corn/Maize (Zea mays) silage

Prawn (M. rosenbergii)
- Cage:10/m^2:50% :- Moore & Stanely (1982)

Distillers dried grains

Crayfish (P. leniusculus)
- Tank:8% :- D'Abramo et al. (1985)

Table 5 contd.

Prawn (M. rosenbergii)
- Tank/Pond:100% (corn-ethanol produced, wet) :- Behrends et al. (1985); Kohler & Killian (1988)

Distillers dried solubles

Shrimp (P.japonicus/P.indicus, P.stylirostris, P.vannamei)
- Tank:4-6% :- Cuzon et al. (1981); Galgani et al. (1989)

Distillers dried grains with solubles

Prawn (M. rosenbergii)
- Pond:2/m^2:20-40% :- Tidwell et al. (1993)

Brewers dried grains

Prawn (M. rosenbergii)
- Tank/Pond:30/m^2:2-10% :- Aquacop (1976)
- Pond:3-5/m^2:100% (wet) :- Kohler & Krueger (1985)

Barley (Hordeum vulgare) grain

Prawn (M. rosenbergii)
- Tank:35% :- Ashmore et al. (1988)

Sorghum/milo (Sorghum bicolor) grain

Prawn (M. rosenbergii)
- Tank:35% :- Asmore et al. (1988)

ROOT CROPS AND STARCHES

Cassava (Manihot esculenta)

Shrimp (General)
- Pond:General:5-10% :- Sumeru (1989); Wood & Coulter (1988)

Prawn (M. rosenbergii)
- Tank/Pond:General:5-20% :- Aquacop (1976); Manik (1976; 1980)

Starch

Shrimp (P. monodon/P. vannamei)
- Tank:3-21% (corn/potato/sago palm) :- Cruz-Suarez, Ricque & Aquacop (1992); Lim & Dominy (1990); Pascual (1989): Penaflorida, Pascual & Tabbu (1992); Vogt, et al (1986)

SINGLE-CELL PROTEINS (SCP)

Bacterial SCP (Pruteen)

Shrimp (P. japonicus)
- Tank:4% :- Cruz-Suarez et al. (1987)
- Pond:2-20/m^2:18% :- Cam et al. (1991)

Table 5. contd.

Algal SCP

Shrimp (P. japonicus/P. indicus)
Tank:8-50% (Spirulina sp.) :- Ahamad Ali (1992); Cuzon et al. (1981)

Shrimp (P. monodon)
- Tank:15% :- Rajyalakshmi et al. (1986)

Crayfish (C. tenuimanus)
- Tank:10% (Dunaliella salina) :- Sommer et al. (1991)

Fungal SCP - Brewers yeast (Saccharomyces cerevisiae)

Shrimp (P. aztecus/P. californiensis/P. japonicus/P. monodon/P. setiferus/P. stylirostris/P. vannamei)
- Tank:4-15% :- Balazs et al. (1973); Brand & Colvin (1977); Cuzon et al. (1981); Deshimaru et al. (1985); Fenucci et al. (1980); Rajyalakshmi et al. (1986); Ricque et al. (1991)

Shrimp (P. vannamei)
- Tank:0.5-1% (live yeast) :- Roques & Dussert (1991)

Shrimp (P. japonicus)
- Pond:2-20/m^2:13% :- Cam et al. (1991)

Prawn (M. rosenbergii)
- Tank/Pond:30/m^2:5% :- Aquacop (1976)

Crayfish (C. destructor)
- Tank:5% :- Merrick & Lambert (1991)

Fungal SCP - Lactic yeast

Shrimp (P. indicus/P. japonicus/P. monodon/P. stylirostris/P. vannamei)
- Tank:3-13% :- Cruz-Ricque et al. (1987); Cruz-Suarez et al. (1987), (1993); Cuzon et al. (1981); Galgani & Ceccaldi (1988); Galgani et al. (1989)

Fungal SCP - yeast (general)

Shrimp (P. japonicus)
- Tank:20-21% (petroleum yeast) :- Deshimaru & Shigeno (1972)
- Tank:20-26% (YR-200/B) :- Teshima et al. (1991)

Shrimp (P. chinensis)
- Tank:20-40% (diet yeast) :- Zhang (1992)

Shrimp (P. californiensis)
- Tank:5-10% (n-paraffin yeast) :- Brand & Colvin (1977)

Shrimp (P. monodon)
- Tank:15% (torula yeast) :- Ung & Junilla (1989)

Prawn (M. rosenbergii)
- Tank:10-40% (sugarcane yeast) :- Zimmermann & Cohen (1991)

Table 5 contd.

Lobster (H. americanus)
- Tank:4-20% :- Gallagher (1976)

Crayfish (C. destructor)
- Tank:5% (torula yeast) :- Merrick & Lambert (1991)

MISCELLANEOUS FEED INGREDIENTS

Ipil-ipil (Leucaena leucocephala) leaf meal

Shrimp (P. monodon)
- Tank:10-35% :- Pascual & Catacutan (1990); Penaflorida, Pascual & Tabbu (1992); Vogt et al. (1986)

Prawn (M. rosenbergii)
- Tank/Pond:30/m^2:7.5-40% :- Aquacop (1976)

Sugarcane (Saccharum sp.) Bagasse and By-products

Shrimp (P. vannamei)
- Pond:20/m^2:100% :- Freeman et al. (1992), Visscher & Duerr (1991)

Shrimp (P. monodon)
- Pond:0.3/m^2:100% :- Subosa (1992)

Crayfish (P. clarkii)
- Pond:General:100% :- Avault & Brunson (1990); Goddard (1988), Robinson (1989)

- Tank:100% (microbially modified) :- Lewis et al. (1988)

Alfalfa/lucerne (Medicago sativa)

Shrimp (P. indicus/P. stylirostris/P. vannamei)
- Tank:2-9% (protein concentrate) :- Galgani et al. (1989)

Prawn (M. rosenbergii)
- Pond:General:4% :- Corbin et al. (1983)

Mangrove (Rhizophora mucronata) leaves

Shrimp (M. monoceros)
- Tank:100% (decomposed) :- Vijayaraghavan & Wafar (1983)

Turnip (Brassica sp.) leaves

Shrimp (P. aztecus)
- Tank:5% :- Venkataramiah et al. (1975)

Molasses

Shrimp (P. monodon/P. indicus/P. semisulcatus/M. monoceros)
- Tank:5% (dried cane molasses) Godfred et al. (1991)

Table 5 contd.

Prawn (M. rosenbergii)
- Pond:General:3-4% :- Corbin et al. (1983)

Diatomaceous earth (Zeolite)

Shrimp (P. monodon/P. vannamei)
- Tank:0.5-3% :- Akiyama (1988); Lim & Dominy (1990)

1/ Indicates whether the feeding trials reported were conducted within tanks (glass, plastic, fibre-glass or concrete) or within earthen ponds; in the case of pond studies the initial decapod stocking densities employed are included if known. In addition to the information on the culture system, the range of the dietary inclusion levels tested are presented as percentages.

Table 6. Observed dietary inclusion level (%) of selected processed feed ingredients commonly used within practical complete diets for marine penaeid shrimp and freshwater crustacean species, and suggestions for their maximum dietary inclusion level 1/

Feed ingredient 2/	PENAEID SHRIMP			PRAWNS & CRAYFISH		
	Range	Mean	Max.	Range	Mean	Max.
Blood meal 5-00-381 3/	2-35	5	10	2-11	5	10
Copra meal 5-01-572/3 4/	5-72	10	15	1-44	15	20
Corn grain 4-02-935 5/	9-40	15	25	3-57	25	35
Corn gluten meal 5-28-241	5-10	7	15	5-10	6	15
Cottonseed meal 501617 6/	4-20	10	20	10-16	13	25
Feather meal 5-03-795 7/	15-23	18	15	-	-	20
Fish meal (general)	5-50	25	NL	2-60	20	NL
Fish protein concentrate	2-26	5	15	2-15	4	10
Krill meal 5-16-423 8/	5-53	15	NL	-	-	NL
Meat & bone meal 500388 9/	10-40	15	20	5-12	9	25
Peanut meal 5-03-649/50 10/	18-62	25	20	2-48	20	25
Rice bran 4-03-928 11/	5-52	15	20	3-39	20	30
Shrimp meal 5-04-226 12/	2-86	25	NL	4-44	20	NL
Soybean meal 5-20-637 13/	8-70	20	25	2-68	25	35
Soybean seeds 5-04-597 14/	9-36	15	25	-	-	35
Squid meal 5-04-671	2-71	10	NL	2-20	8	NL
Wheat grain 4-05-268 15/	13-21	18	25	2-60	25	35
Wheat bran 4-05-190	4-12	8	20	7-20	12	30
Wheat gluten meal	2-24	10	20	4-15	12	20
Wheat middlings 4-05-205	4-23	15	25	5-20	15	35
Yeast 7-05-527/34 16/	4-15	8	20	5-10	7	25

1/ Adapted from Tacon (1988); NL - no limit
2/ Feed ingredient name followed by International Feed Number
3/ Although blood meal is a rich source of protein, and particularly the EAAs leucine, valine and histidine, it is very deficient in isoleucine and methionine; consequently due to the antagonistic effect of excess dietary leucine on isoleucine metabolism, animals fed high dietary levels of blood meal may suffer from an isoleucine deficiency. Spray or ring dried meals are recommended over drum dried meals.
4/ Copra meal protein is deficient in methionine and lysine
5/ Uncooked corn contains a protein inhibitor, phytic acid, estrogenic factor, invertase inhibitor and possibly mycotoxin contamination. Cooking improves nutritional value and improves digestibility
6/ Cottonseed protein is deficient in lysine and methionine, and contains phytic acid, estrogenic factor, gossypol, anti-vitamin E factor and cyclopropenoic acid. Free gossypol content varies with processing

method and should be kept to a minimum; screw pressed meals having lower free gossypol levels than directly solvent extracted meals.

7/ Hydrolysed feather meal protein is a rich source of cystine but very deficient in methionine, lysine and histidine; consequently due to the antagonistic effect of excess dietary cystine on methionine metabolism, crustaceans fed high dietary levels of feather meal may suffer from methionine deficiency

8/ Dietary inclusion level may be limited by the fluoride content of the meal

9/ Meat and bone meal protein is usually deficient in methionine and tyrosine, and of variable quality (ie. ash, methionine and lipid content), with the possibility of salmonella contamination (in non-solvent extracted meals). The high ash content usually limits the use of high dietary inclusion levels due to the antagonistic effect of excess dietary calcium on trace mineral metabolism

10 Peanut meal protein is deficient in methionine and lysine, and contains a protease inhibitor, phytohaemagglutinin, phytic acid, saponin, estrogenic factor, and possible mycotoxin (ie. aflatoxin) contamination. The decorticated material should be used when possible

11 Although dietary inclusion levels as high as 50% have been successfully used, the lipid within the meal is prone to oxidation with the consequent development of rancidity. The high fibre content of the meal is usually its major limiting factor, together with the presence of the anti-nutritional factors lectin (haemagglutinin), phytic acid and an anti-thiamine factor (thiaminase)

12 High dietary inclusion levels may be limited by the high crude fibre content of the meal

13 Soybean meal protein is deficient methionine and lysine, and contains a protease inhibitor, phytohaemagglutinin, glucosinolate, phytic acid, saponin, estrogenic factor, flatulence factor, anti-vitamin E, A, D and B12 factors

14 Heat processed full-fat soybeans

15 Uncooked wheat contains a protein inhibitor, phytohaemagglutinin, phytic acid, estrogenic factor, flatulence factor, amylase inhibitor and dihydroxyphenylalanine. Cooking improves nutritional value and improves digestibility

16 Yeast protein is deficient in methionine, and limiting factor is usually (depending upon the species) palatability (ie. bitter taste of brewers yeast).

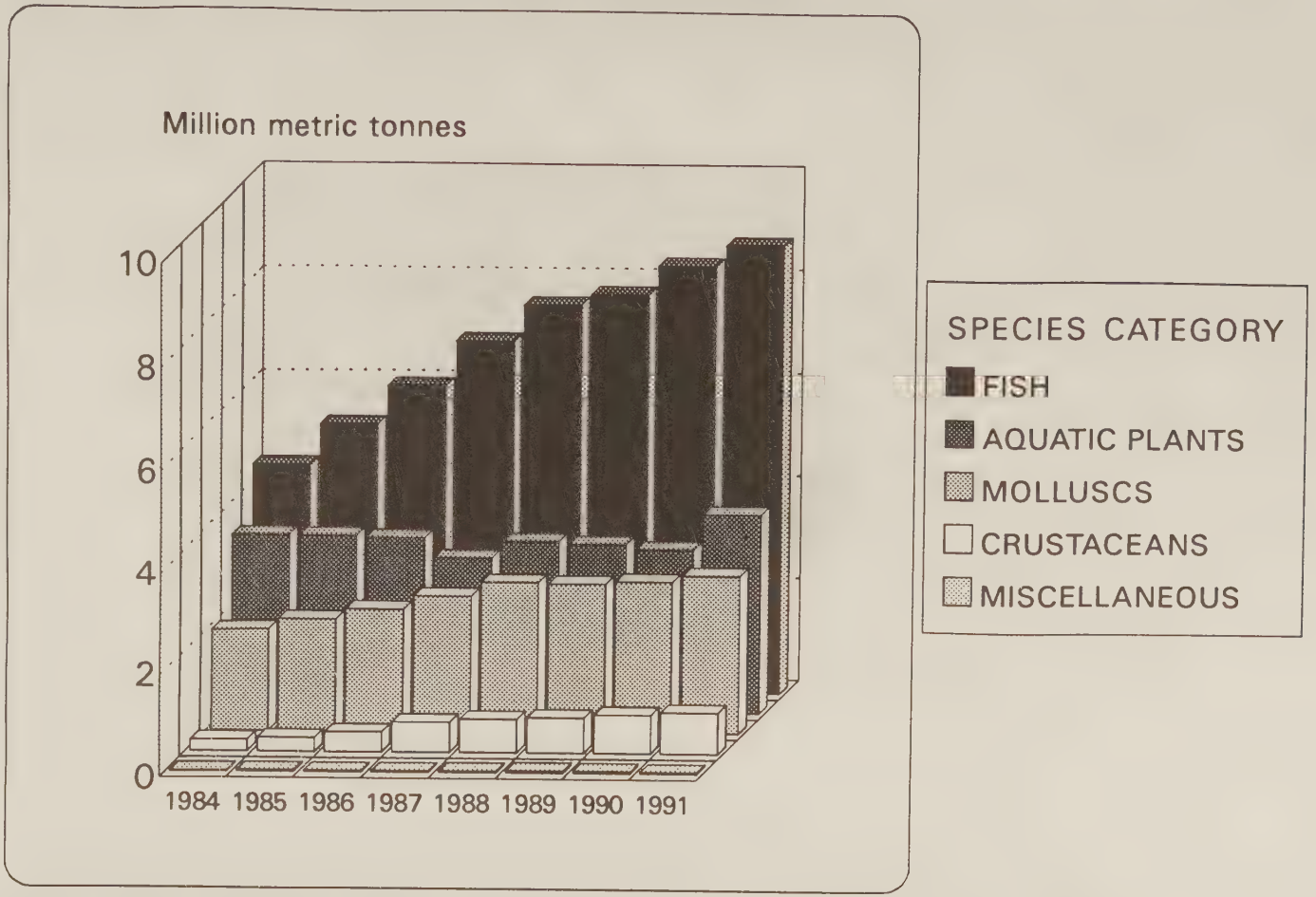
Table 7. Utilization of world fishery resources for fish meal and fish oil production 1/

UTILIZATION OF WORLD FISHERY RESOURCES AND FISHMEAL PRODUCTION 1985-1991 (values given in '000 mt)							
	1985	1986	1987	1988	1989	1990	1991
TOTAL WORLD LANDINGS 1/	86,324	92,804	94,379	99,016	100,208	97,434	96,926
- For human consumption	60,168	64,094	66,641	69,809	70,878	70,029	69,157
- % total landings	69.7%	69.1%	70.6%	70.5%	70.7%	72.2%	71.4%
- For other purposes	26,156	28,710	27,738	29,207	29,330	27,405	27,769
Reduction 2/	24,956	27,110	26,188	27,557	27,730	25,905	26,169
- % total landings	28.9%	29.2%	27.7%	27.8%	27.7%	26.6%	27.0%
- % total catch	31.7%	32.3%	31.1%	31.4%	31.2%	30.4%	31.1%
Miscellan. purposes	1,200	1,600	1,550	1,650	1,600	1,500	1,600
Total fishmeal production 2/	6,311	6,689	6,487	6,837	6,875	6,372	6,367
- Fishmeal from white-fish	217	190	187	198	192	150	148
- % total fishmeal	3.4%	2.8%	2.9%	2.9%	2.8%	2.4%	2.3%
Hake meal	0.36	4.2	22.8	39.6	41.4	21.2	26.9
Other white-fish	217	186	165	159	151	129	121
- Fishmeal from oily fish	5,793	6,291	6,072	6,390	6,429	6,017	6,079
- % total fishmeal	91.8%	94.0%	93.6%	93.5%	93.5%	94.4%	95.5%
Anchoveta meal	313	745	499	648	835	592	725
Jack mackerel meal	332	256	399	466	510	529	652
Pilchard meal	934	860	706	432	461	293	307
Menhaden meal	279	269	303	229	210	203	211
Capelin meal	144	144	126	161	112	117	47
Tuna meal	38.6	41.5	54.2	53.3	48.5	41.7	40.4
Herring meal	24.3	24.3	29.4	37.2	34.3	40.8	39.8
Clupeoid fish meal	35.1	33.1	36.5	37.3	59.5	62.5	71.5
Oily-fish meal (others)	3,692	3,918	3,918	4,327	4,158	4,137	3,985
- Miscellaneous meals 3/	15.9	19.2	25.8	25.9	28.5	10.5	10.0
- % total fishmeal	0.3%	0.3%	0.4%	0.4%	0.4%	0.2%	0.2%
- Fish solubles	286	189	201	222	225	195	130
- % total fishmeal	4.5%	3.0%	3.1%	3.5%	3.5%	3.2%	2.1%
Total fishmeal exports	3,170	3,265	3,283	3,214	3,754	3,225	3,316
- Value 1,000,000 US $	932	1,109	1,228	1,601	1,641	1,335	1,550
Total oil & fat production 4	1,496	1,671	1,453	1,556	1,631	1,408	1,373
- Fish liver oils	31.3	24.6	34.0	39.7	31.5	24.3	25.6
- Fish oils & fats (other)	1,464	1,646	1,419	1,516	1,599	1,384	1,347
Total oil & fat exports	990	793	686	836	792	736	653
- Value 1,000,000 US $	298	202	181	292	194	206	234

1/ Total world landings includes fish and shellfish, and excludes whales, seals, other aquatic mammals and aquatic plants (FAO, 1993b)
2/ Only whole fish destined for the manufacture of oils and meals is included.
3/ Miscellaneous meals of aquatic origin include crab meal, shrimp meal and crustacean meals
4/ Oils and fats, crude or refined, of aquatic animal origin

FIGURE 1. WORLD AQUACULTURE PRODUCTION BY SPECIES CATEGORY 1984-1991

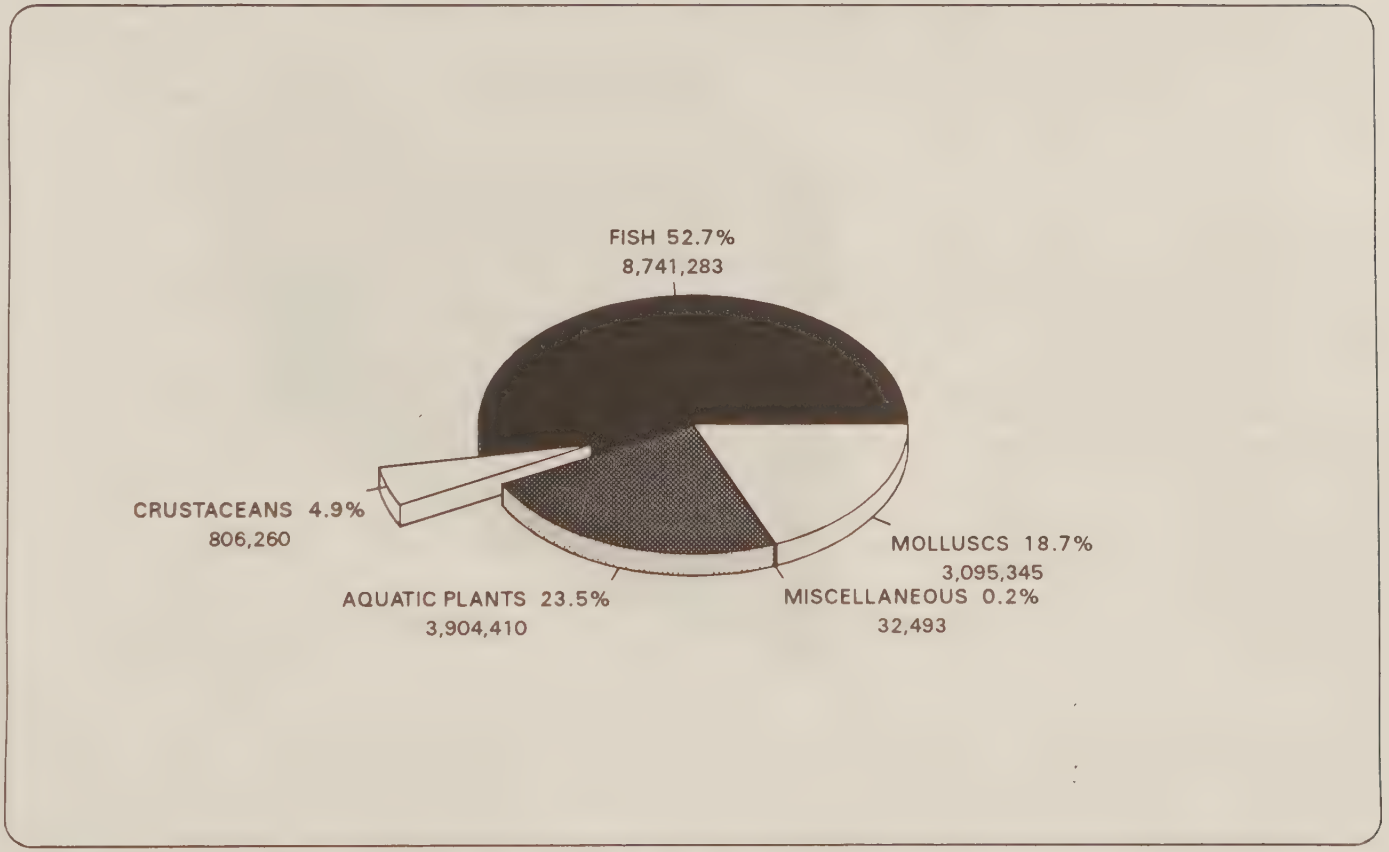
(values given in 000'000 mt)



Source: FAO (1993)

FIGURE 2. TOTAL WORLD AQUACULTURE PRODUCTION BY WEIGHT IN 1991

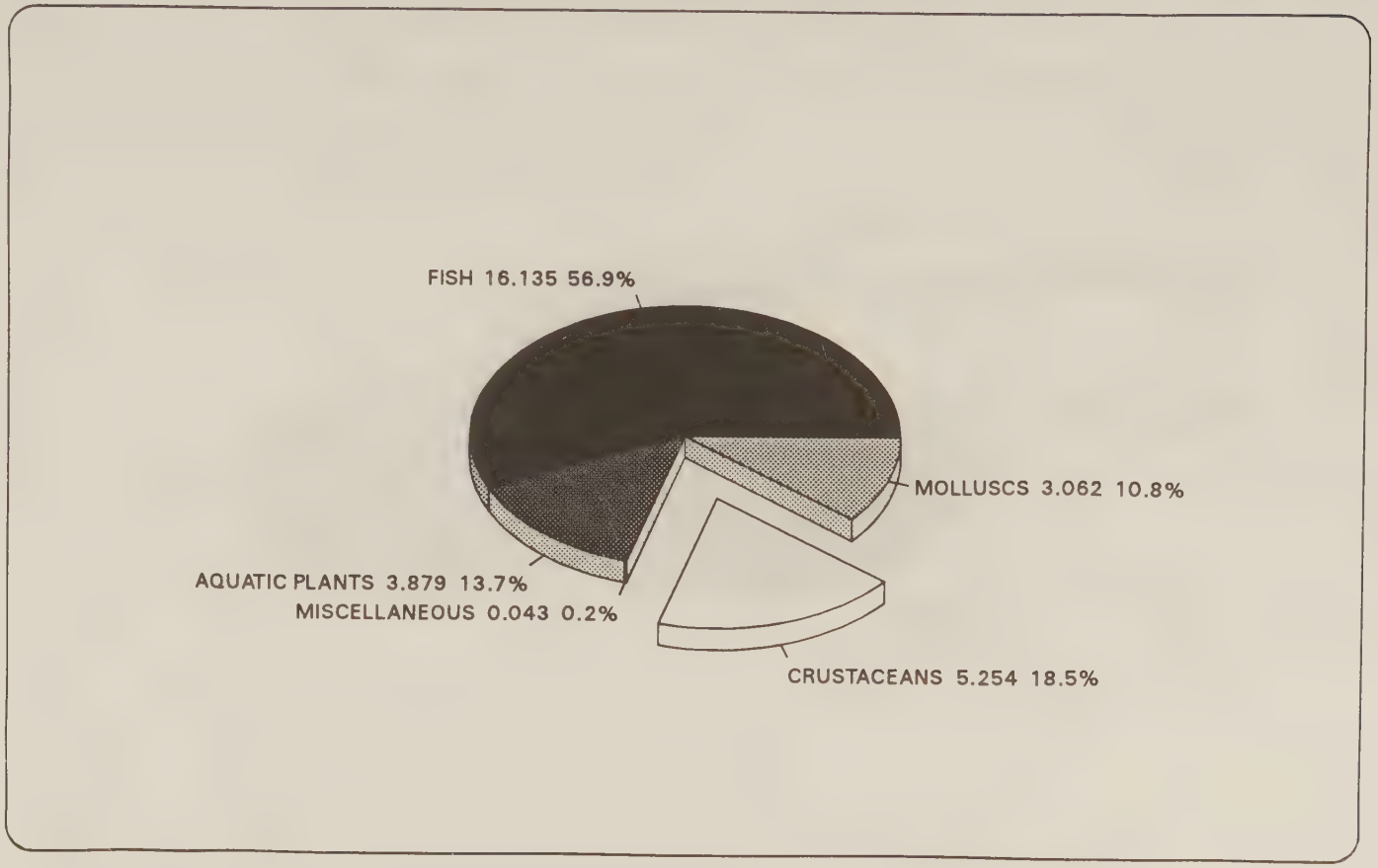
(values given as % of total and in metric tonnes)



Total aquaculture production - animals & plants 16,579,791 mt
Total value of aquaculture production - 28.4 thousand million US $
Source: FAO (1993)

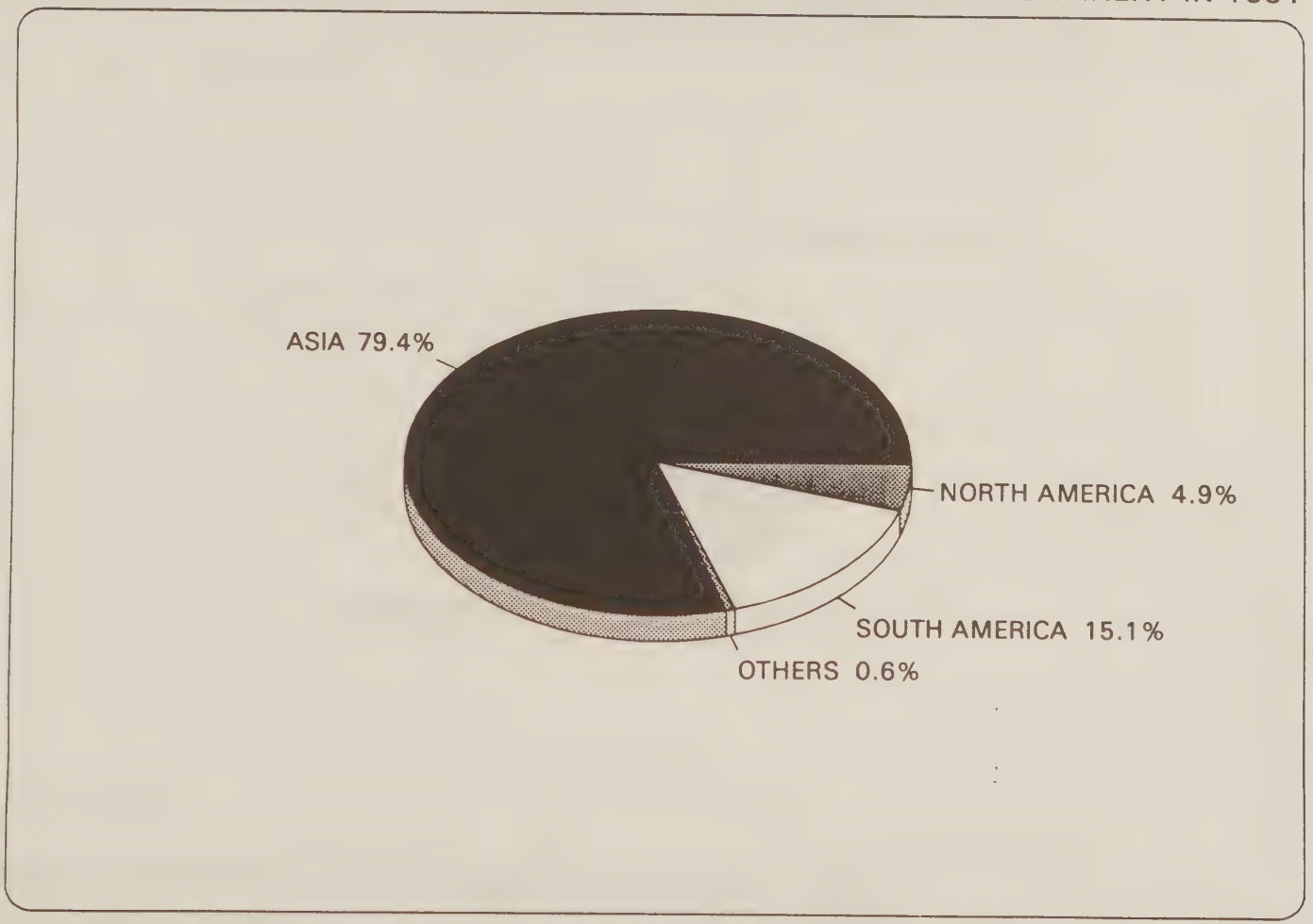
FIGURE 3. TOTAL WORLD AQUACULTURE PRODUCTION BY VALUE IN 1991

(values given in thousand million US $)



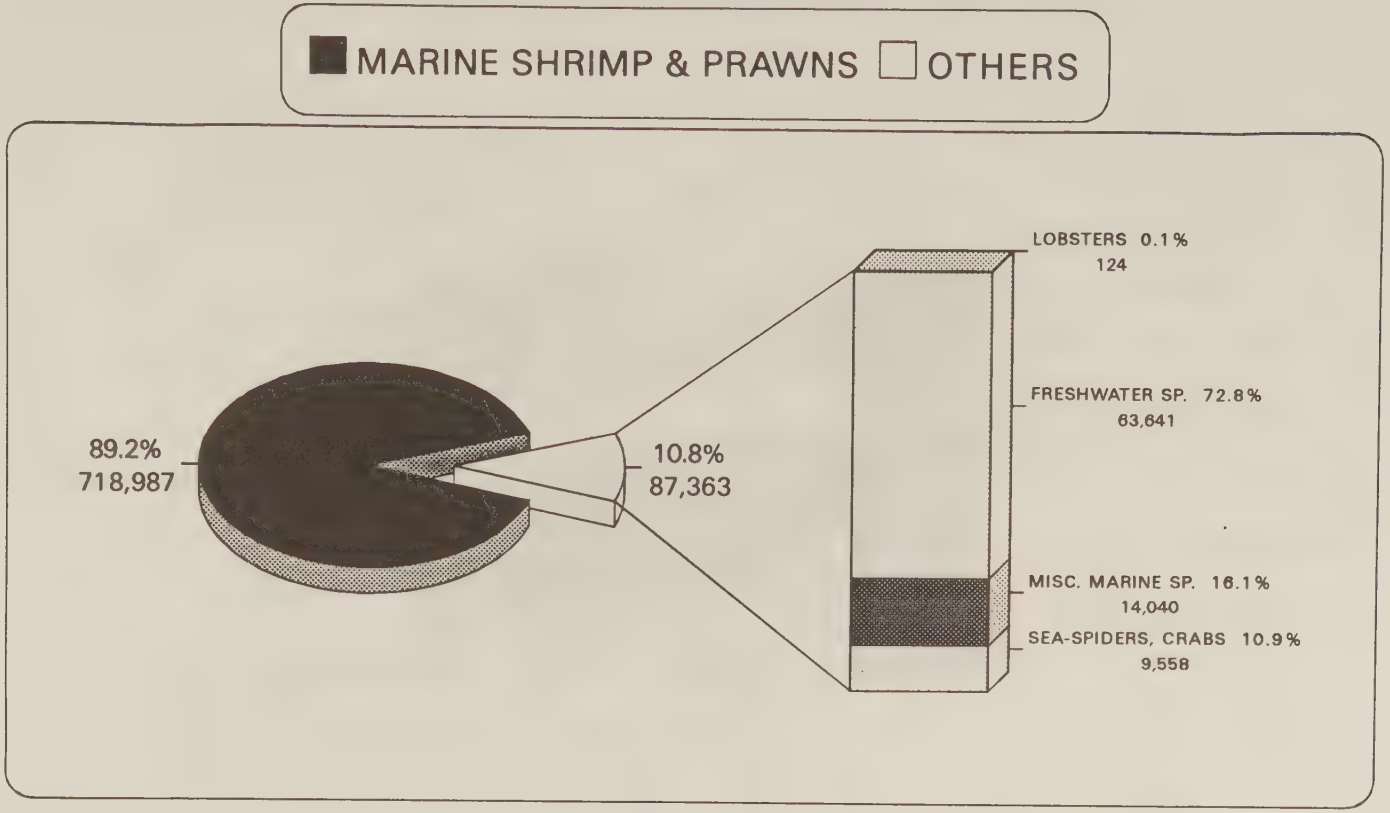
Total value of crustacean aquaculture production - 5.2 thousand million US $
Source: FAO (1993)

FIGURE 4. TOTAL CRUSTACEAN AQUACULTURE PRODUCTION BY CONTINENT IN 1991



Source: FAO (1993)

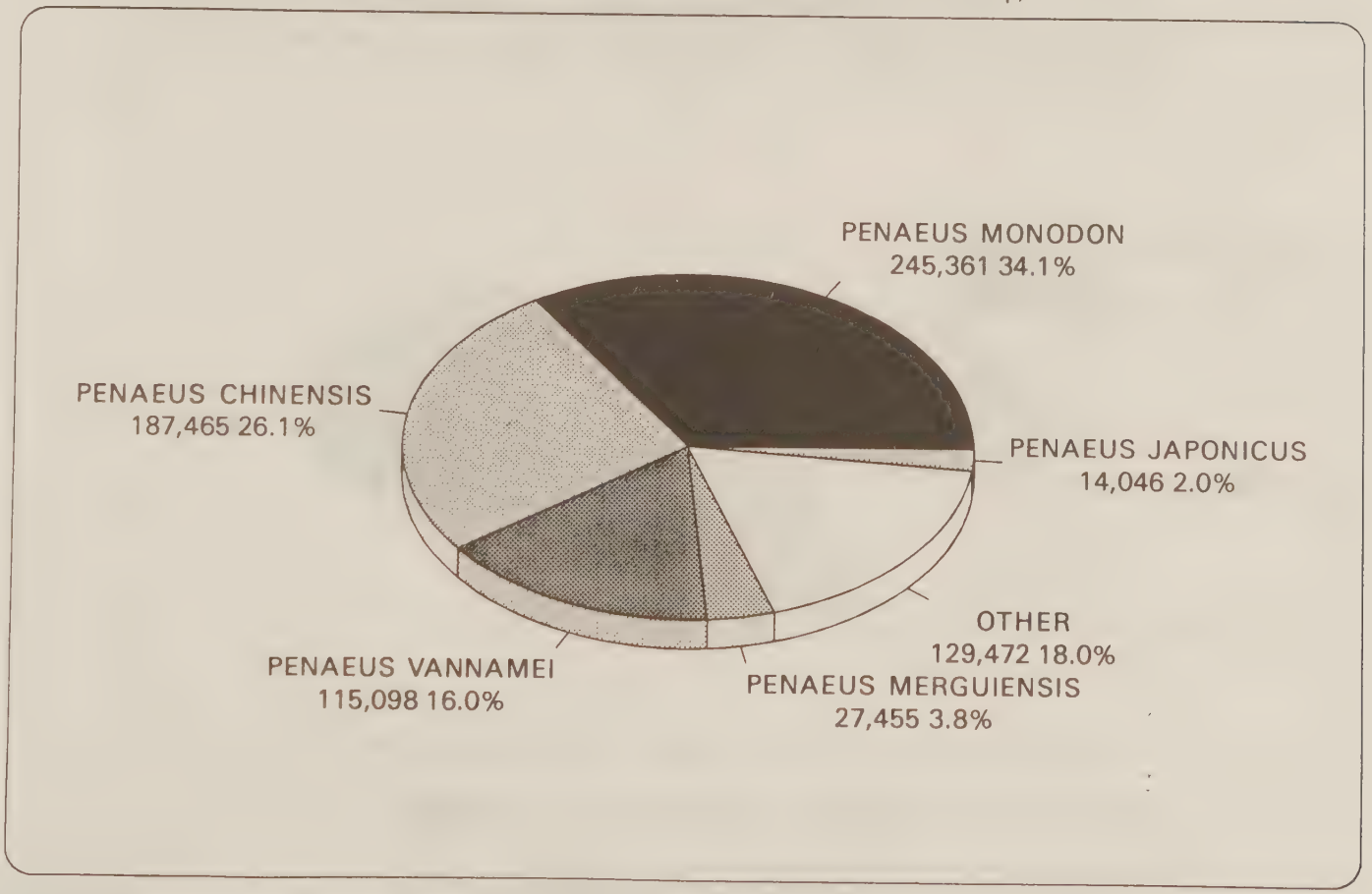
FIGURE 5. TOTAL WORLD CRUSTACEAN AQUACULTURE PRODUCTION IN 1991
(values given as % of total and in metric tonnes)



Total crustacean aquaculture production in 1991 - 806,260 mt
Total value of production - 5,254,649,000 US $
Source: FAO (1993)

FIGURE 6. TOTAL WORLD SHRIMP AQUACULTURE PRODUCTION IN 1991

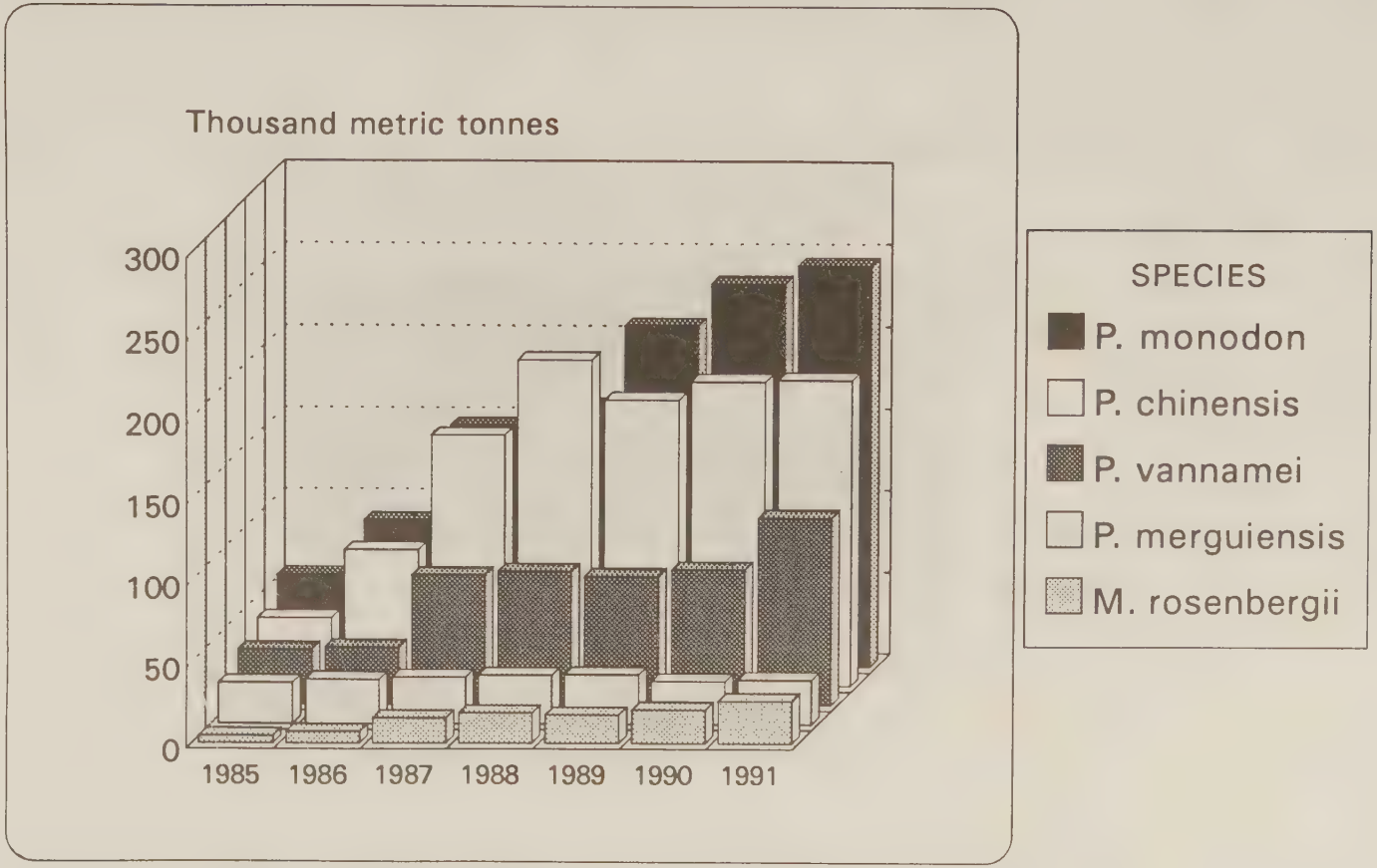
(values given in metric tonnes and as % of total cultured shrimp)



Total farmed shrimp production - 718,987 mt
Source: FAO (1993)

FIGURE 7. TOP FIVE CULTURED CRUSTACEAN SPECIES 1985-1991

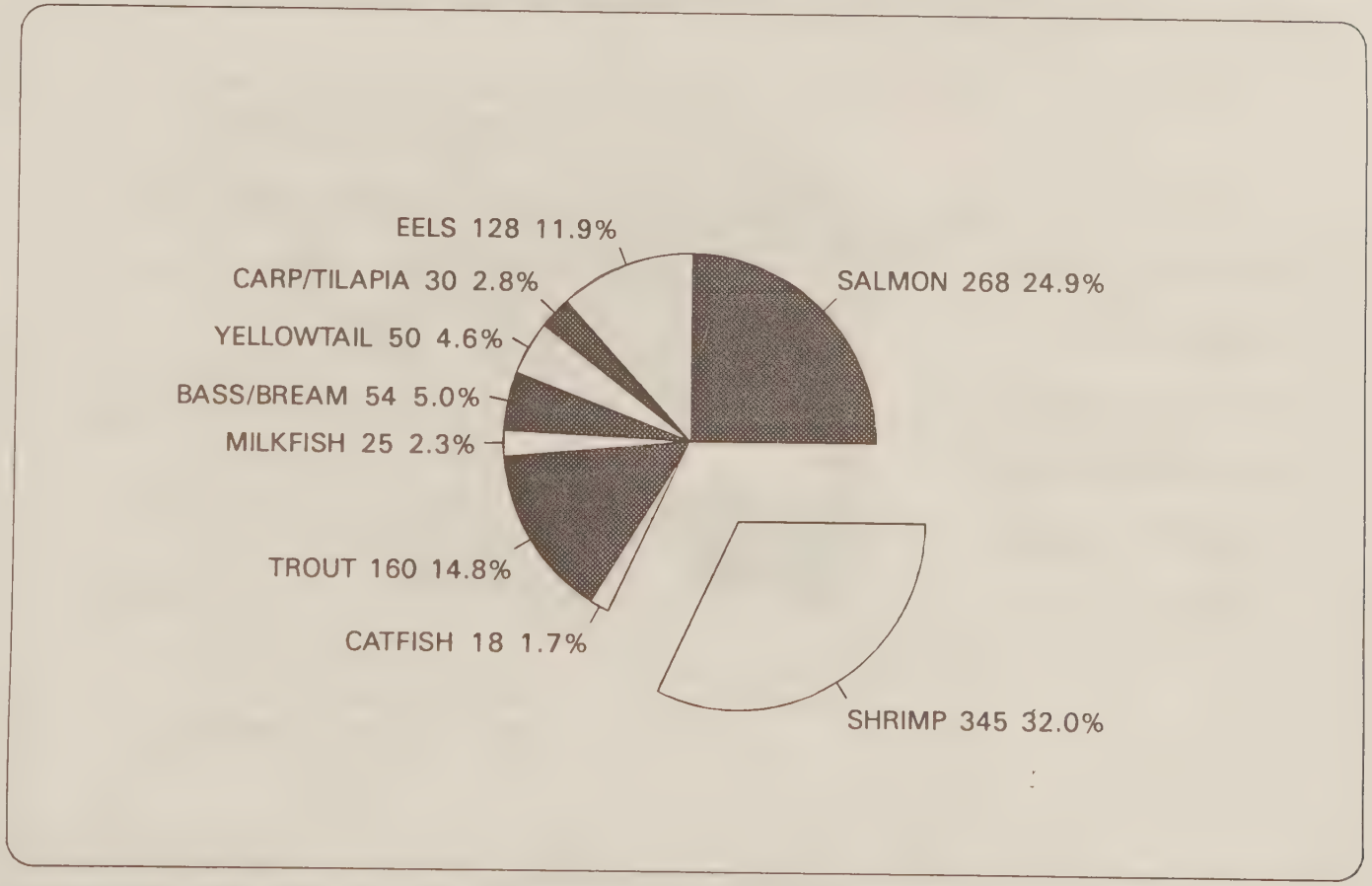
(values given in '000 mt)



M - Macrobrachium; P - Penaeus

Source: FAO (1993)

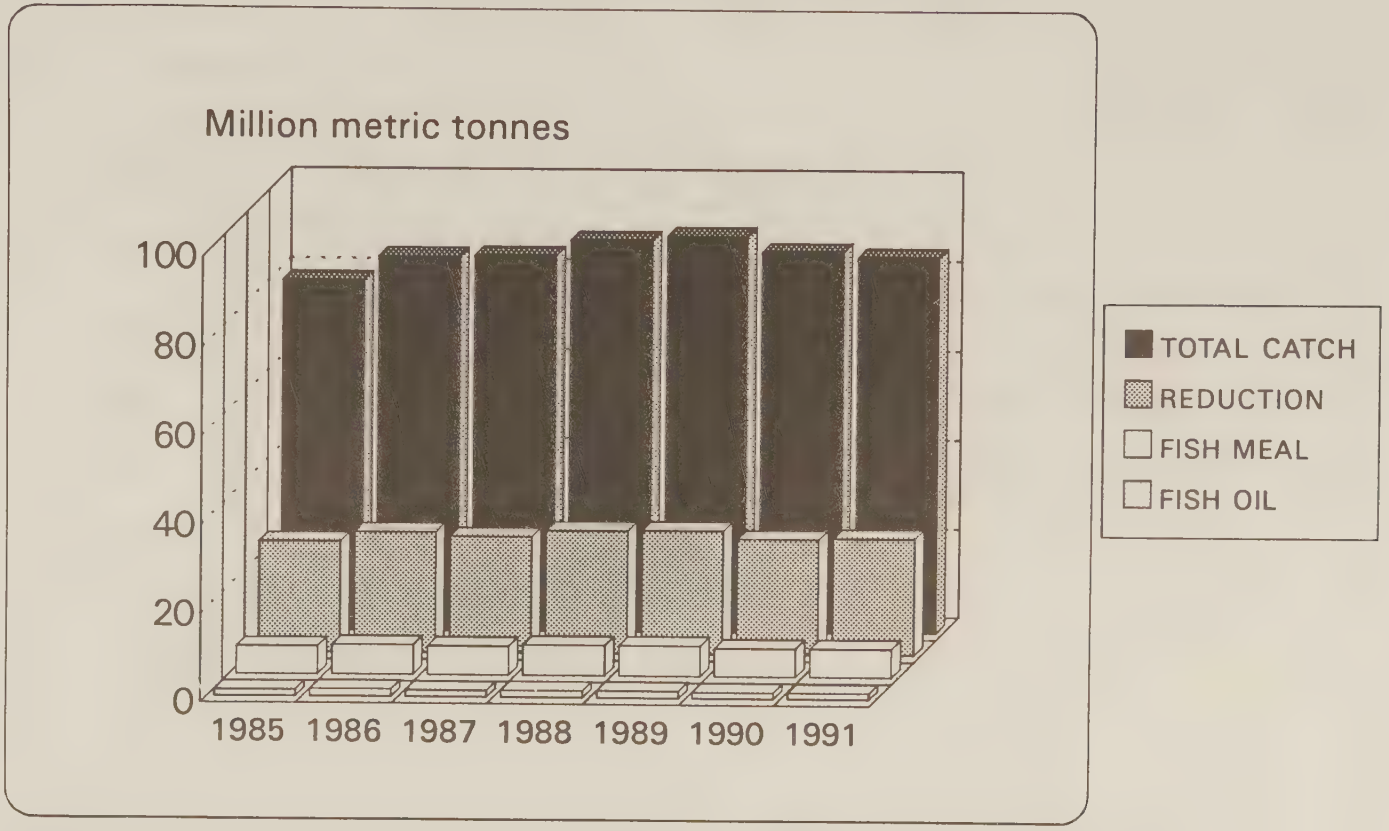
FIGURE 8. FISH MEAL CONSUMPTION BY AQUACULTURE SPECIES IN 1992
(values given as % and '000 metric tonnes)



Total reported fish meal used within aquafeeds 1,078,000 mt
Source: I.H.Pike, personal communication, IFOMA March 1993

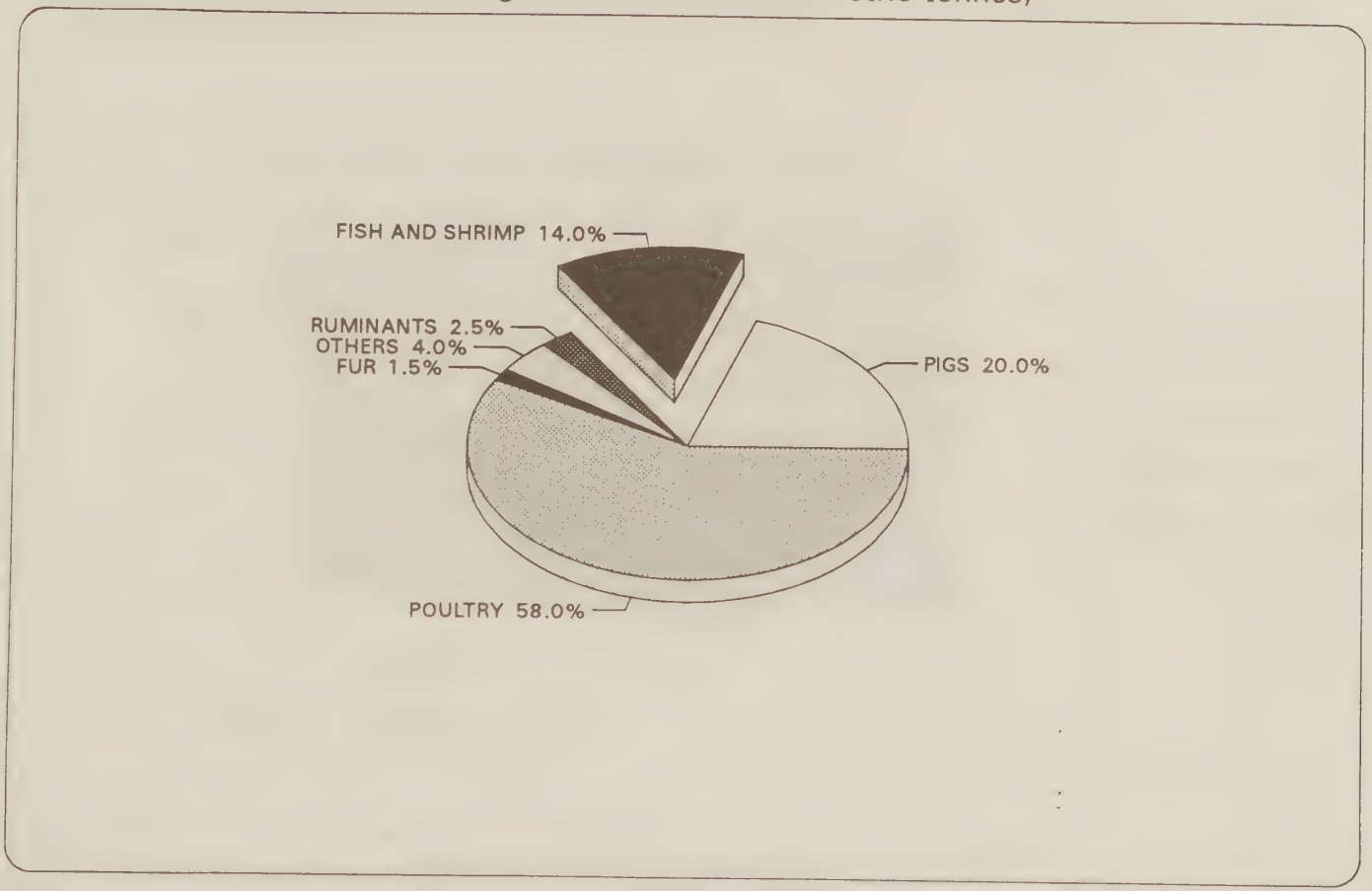
FIGURE 9. UTILIZATION OF THE WORLD FISH & SHELLFISH CATCH
- FISH MEAL AND FISH OIL PRODUCTION

(values given on a wet weight basis except for fish meal)



Reduction - includes only the use of whole fish destined for the manufacture of fish oils and fish meals
Source: FAO (1993a, 1993b)

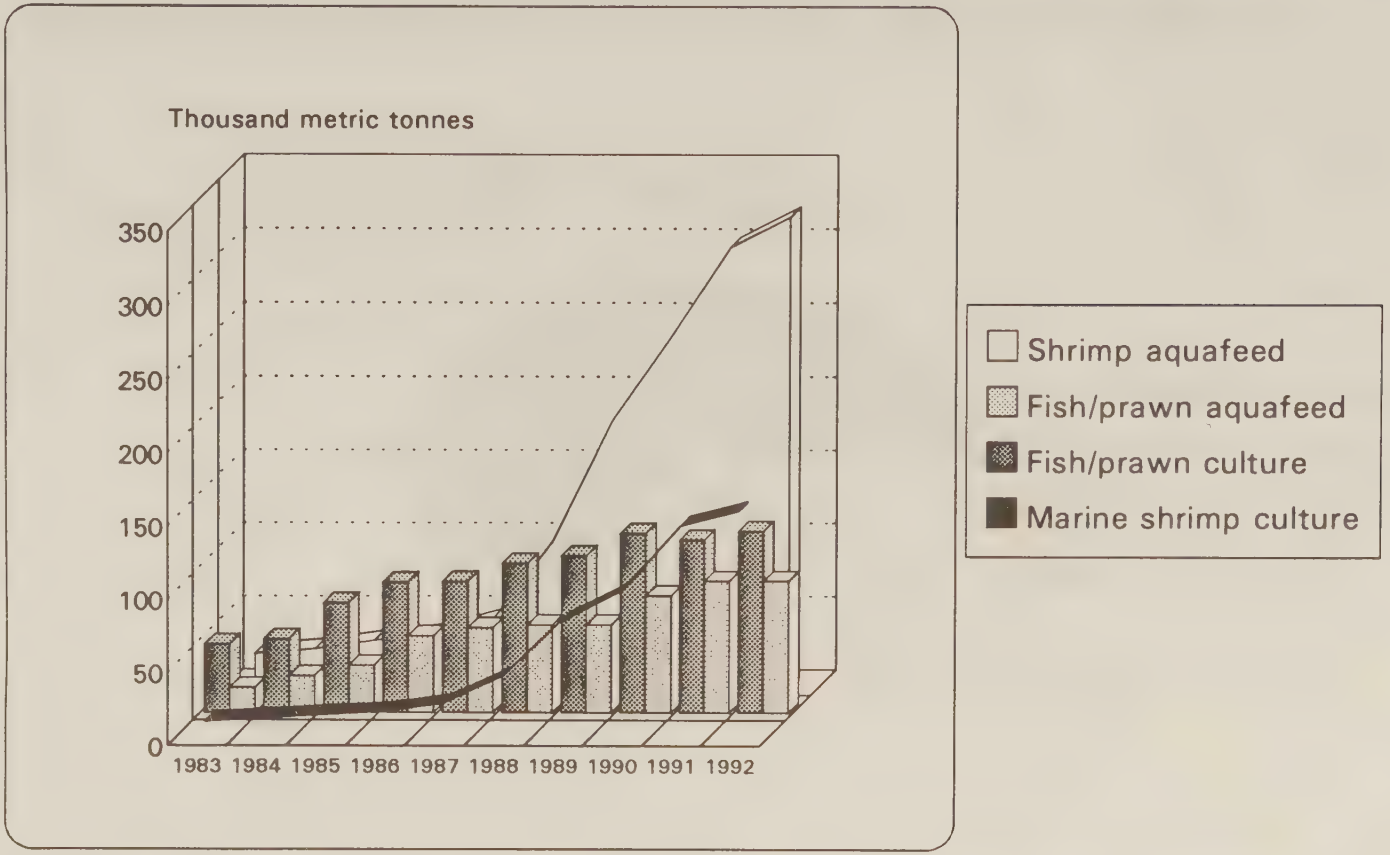
FIGURE 10. GLOBAL USE OF FISH MEAL IN LIVESTOCK AND AQUAFEEDS
(values given as % and '000 metric tonnes)



Fish meal consumption by animal species in 1990
Source: Pike (1991)

FIGURE 11. GROWTH OF THE DOMESTIC AQUACULTURE AND AQUAFEED SECTOR IN THAILAND

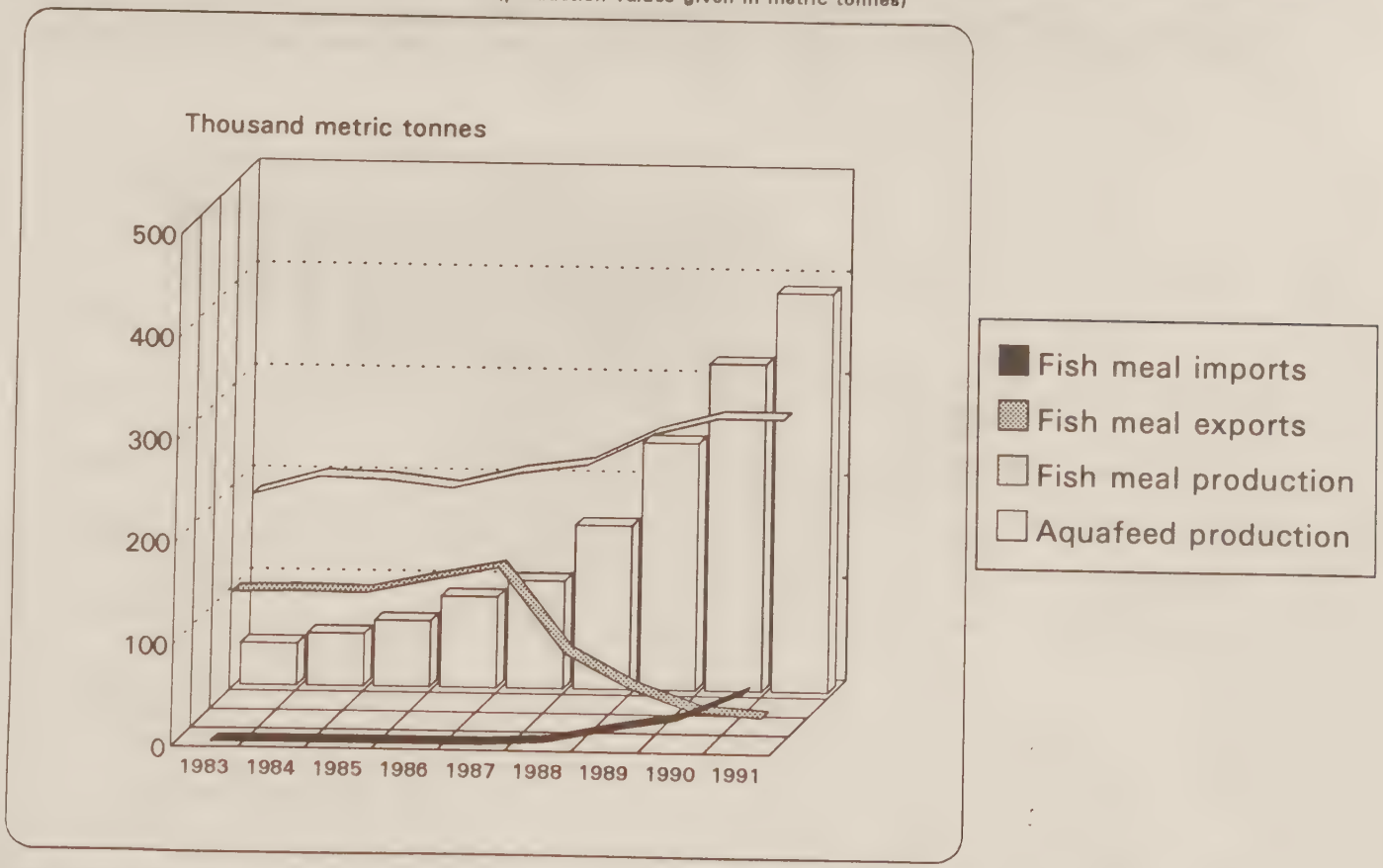
(production values given in metric tonnes)



Total compound aquafeed production for domestic use has increased from 40,736 to 410,000 mt (78% shrimp aquafeed) from 1983 to 1992; Thailand also exported 11,446mt of shrimp aquafeed in 1992
Source: Jantrarotai (1993)

FIGURE 12. FISH MEAL PRODUCTION, IMPORTS AND EXPORTS IN THAILAND 1983-1991

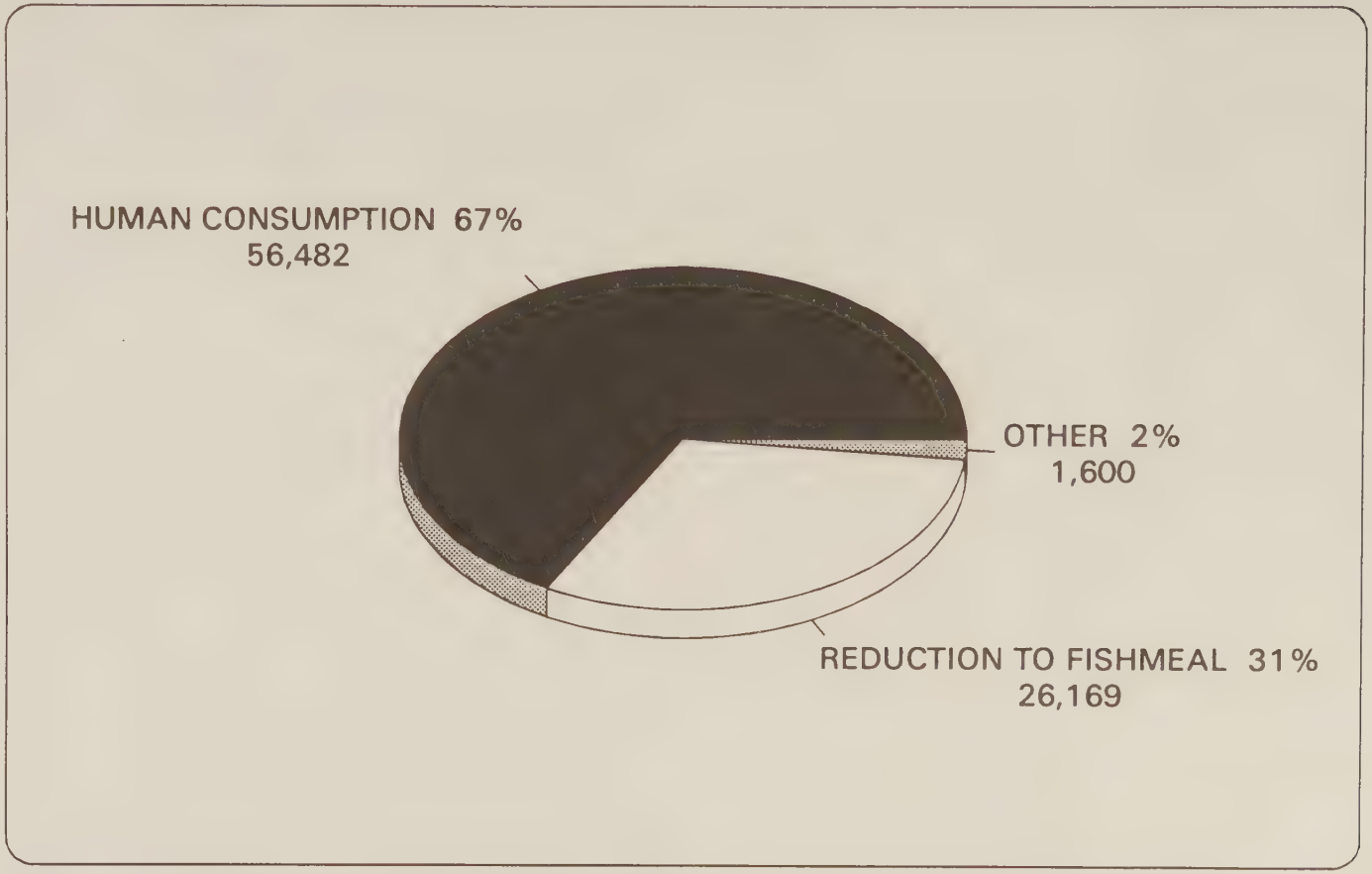
(production values given in metric tonnes)



Fish meal production increased from 204,811 to 285,000 mt from 1983 to 1991, whereas exports decreased from 128,007 to 11,035mt and imports increased from 0 to 53,119 mt from 1983 to 1991
Source: Data from FAO (1993b) and Jantrarotai (1993)

FIGURE 13. UTILIZATION OF THE WORLD FISH AND SHELLFISH CATCH IN 1991

(values given as % and '000 mt)



Total world fish and shellfish catch in 1991 was 84,251,000 mt of which 26,169,000 mt was reduced into 6,367,000 mt of fish meal and 1,373,000 mt of fish oil; fish meal and fish oil exports in 1991 were valued at 1,550 and 234 million US $ respectively (Source: FAO, 1993b)